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THE WORLD DATA CENTRE FOR ATMOSPHERIC ELECTRICITY AND GLOBAL CHANGE MONITORING

a report by Hans Dolezalek

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This issue of European Science Notes Information Bulletin (ESNIB) 92-02 combines a special report, The World Data Centre for Atmospheric Electricity and Global Change Monitoring by Hans Dolezalek, with news, notes, and abstracts. The latter section contains reports on Oceanography, Mathematics, Structural Acoustics, Materials, Electronics, and news from the National Science Foundation. The value of the ESNIB to Americans is to call attention to current activity in European science and technology and to identify the institutions and people responsible for these efforts. The ESNIB authors are primarily ONR Europe staff members; other reports are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the U.S. Army Research, Development, and Standardization Group. Scientists from the U.S. who are traveling in Europe may also be invited to submit reports.

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Commanding Officer . . . . . CAPT John M. Evans, USN
Scientific Director . . . . . Dr. Arthur M. Diness
Editor . . . . . Ms. Connie R. Orendorf

THE WORLD DATA CENTRE FOR ATMOSPHERIC ELECTRICITY AND GLOBAL CHANGE MONITORING . . . . . Hans Dolezalek

The World Data Centre for Atmospheric Electricity and Global Change Monitoring

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The World Data Centre for Atmospheric Electricity and Global Change[1] Monitoring

by Hans Dolezalek, was a physicist serving as Liaison Scientist at the Office of Naval Research European Office, London. He is currently specializing in remote sensing (with emphasis on the ocean), and questions about applications of atmospheric electricity for global change. Before this assignment, he acted as a Scientific Officer of the Remote Sensing Program in the Ocean Sciences Directorate, Office of Naval Research Headquarters, Washington, D.C.

Introduction

Man is able to disturb the ecological equilibrium in his environment, or whatever the situation of nature without man should be called. This is an old truth; witness the deforestations in Dalmatia, China, or Spain centuries ago. The human impact has become more significant in the last 150 years or so, and even more so in the last 4 or 5 decades. Today, it is a matter of public concern; indeed, it is a powerful political argument. This public concern has led to emotional public discussions which often lack sound scientific basis. Catastrophic developments with a perceived threat to the well-being or even survival of man or species of plants or animals have been predicted and contradicted, not only in the public press but also in scientific journals and in declarations of political bodies. In addition, there are statements that the natural equilibrium may not be as stable as it was assumed before, and thus more vulnerable to human activities. These statements have also been contradicted. Powerful political, corporative persons and bodies have switched sides in this discussion, or have gone from optimism and activity to pessimism and despair. Considerable amounts of money have been allocated by governments to either further investigate the ecological situation or to do something to reduce any potential threat. Research programs for such investigations abound on many scientific and organizational levels.

There are few doubts that mankind needs a system to monitor on a continuing basis the ecological situation often cited under the name global change. Data collection efforts should be continued, and new and well-prepared efforts started. The continuation of older efforts is especially valuable when the observations began before human activity rose to the present scale.

The older data acquisition systems often lack the reliability or precision we desire or need. They often did not aim directly at the most important parameters. In such cases, we must investigate how they still can be made useful for modern purposes of global change monitoring. At the same time, the systems must be planned so that reliability and precision correspond to modern requirements and possibilities, but also continue to provide data that can be compared with the older collections.

A worthwhile endeavor may be to identify institutions where continuous data recordings have been stored. Decades ago, it was a general practice never to destroy measuring data. Although storage is easier and cheaper now, data is commonly destroyed. We hope to find older data collections that could be useful for global change purposes, especially if modern storage methods can be applied to them. The most likely place to find older data is where there has been steady scientific financial support for research; i.e., less dependent on producing quick results.

In the search for desirable new data systems, unorthodox indicators may have a value that was formerly unrecognized. They may provide some benefits to global change investigations. Particularly interesting are data systems that integrate the whole earth; i.e., providing global information from one or a few measuring points. Locally obtained data that represents only a smaller area will still be important for that area. However, when truly integrating data are not available, we must resort to a global integration of local values. In any case, they sometimes may be used for calibration.

Amplifying elements can have special merit because parameters important for the judgement on global change often undergo only very slow and slight variations with time. We may want to look for processes (or "trigger processes") in which small causes can have large consequences.

The points made in this introduction about old data systems and new requirements may or may not apply to a somewhat neglected field of environmental science--atmospheric electricity.

[1] An umbrella for all present efforts to monitor and evaluate the potential for world-wide climatic change partially caused by human activities. The "greenhouse" effect, ozone hole, ocean warming, are part of Global Change.

Global Change Monitoring and Atmospheric Electricity

We are not surprised that scientists looking at what is often called Earth System Science have asked whether atmospheric electricity could be expected to make a valuable contribution to monitoring world-wide environmental parameters; e.g., in a meeting of the International Council of Scientific Unions' *ad hoc* planning group in April 1986. Asking such questions seems to be natural. The atmospheric electricity literature abounds with papers on relationships between the electrical and other parameters of the atmosphere. We would have to write a book to try to reproduce these discussions. Not doing this, but describing this discussion in general would deny credit to many colleagues who should be credited. Instead, we begin our present consideration by seeing the situation from the point of view of the global change people who are not versed in atmospheric electricity details.

The global circuit of atmospheric electricity, in all its parts, is influenced by meteorological processes. These influences are incorporated in the current that flows in the global circuit. As the electric conductivity of the troposphere and the stratosphere is so much lower than that of the ground and that of the ionosphere, the potential difference between these two highly conductive layers indicates the strength of the global circuit current and its variations with time. In measuring the electric field or the air-earth current density at any one station (which in turn, are both indicators of that potential difference), we may obtain information about those meteorological processes that, world-wide, produce the influences on the global circuit current. At the same time, the data obtained by measuring the electric field and/or the air-earth current density are also influenced by local events at and above the measuring stations. These events may be generators for local electric circuits or may cause variations of resistances in the circuit. Therefore, we must basically consider that in the data thus obtained, we are witnessing influences both from processes that occur on the whole globe at the same real time, as well as from purely local events. If the scientists in atmospheric electricity had a chance to separate these shares, we might have a tool of significance for global change problems. This possibility is a topic of discussion and doubt.

Also, atmospheric electricity data can be sensitive indicators of other processes in the atmosphere. For example, the number density of fast ions is used as a nonspecific (i.e., integrating the effects of all ionizing sources), but a very sensitive, simple, and relatively cheap indicator of atmospheric radioactivity. Again, many related papers have been published[2].

Evaluating the present situation from this vantage point, we can perceive three main approaches from atmospheric electricity to the global change monitoring effort.

1. Measure local parameters at many places and attempt meaningful integrations for the results over areas of global importance, optimally for the whole globe
2. Measure local parameters and follow local processes at locations where they may be representative for large global areas; expectation is that this will be the case on the oceans far from the shores
3. Find global shares in local measurements and derive global information from a rather small number of local stations.

As indicated above, literature is plentiful. Especially for approach 1; it begins almost with the 20th century, is at least briefly summarized in Israel (1973, p. 393, *Secular Changes*, p. 401 *Anthropogenic Influences*), Landsberg (1977, his banquet address in 1974), and (in a different manner) Dolezalek (1978). Approach 1 is discussed in much detail throughout the textbooks of Chalmers (1967) and Israel (1970, 1973) and in the proceedings of the eight international conferences on atmospheric electricity (see page 10). However, we are confronted with a problem of significant complexity (see Reiter 1984). We may also expect that the work done by Tammet and coworkers in Tartu will produce important insights (see Dolezalek 1991). Local radioactivity as well as the potential for global radioactivity changes, including the krypton 85 problem (Boeck; e.g., 1977), will be reflected in atmospheric electricity data.

Approach 2, too, has experienced attention, especially in oceanic measurements of atmospheric electric conductivity, or the number density of cluster ions (also called "fast" or "small" ions); e.g., the papers by Gunn (1964), Mühleisen (1968), Cobb and Webb (1970), Cobb (1973), and Morita and Ishikawa (1977).

While approaches 1 and 2 deserve a new critical evaluation for the immediate purposes of global change monitoring, including designs for practical application, approach 3 is the most difficult but potentially the most useful. The recent interest in global change monitoring by atmospheric electricity seems to be concentrating on this approach. Individual aspects have been considered now and then in the past; e.g. see Markson (1977).

[2] e.g., recently: Israelsson and Knudsen (1986), Warzecha (1987), and Retalis and Pitta (1989).

A first general discussion on global change aspects of atmospheric electricity took place at the Eighth International Conference on Atmospheric Electricity (8CAE), held in June 1988 in Uppsala, Sweden (Lundquist 1988). There was a specific day dedicated to a general discussion of this issue (not in the proceedings). During the main meeting, there was one particular paper (Dolezalek 1988) and several other papers not dealing specifically with global change problems but presenting related scientific facts (e.g., Markson 1988, Morozov and Selezneva 1988, and others). Since then, the ICAE has initiated a Global Atmospheric Electricity Measurement program (GAEM) (Reiter 1990).

An *ad hoc* idea presented at 8CAE (but not yet investigated in any scientific sense) is the speculation that by measuring the total electrical resistance between ion sphere and ground, one could obtain an immediate measure of the total aerosol burden of the earth's atmosphere (Dolezalek 1988). Recently, another hypothesis was presented in depth by Williams and Renno (1991). They suggest that the Earth-ionosphere potential difference is a parameter that nonlinearily depends on the warming or cooling of the Earth's atmosphere. There is the problem involved that we have no confirmed knowledge on the quantitative relationship between lightning occurrence and Earth-ionosphere potential difference. A recent paper by Earle and Williams (1991) discusses one important aspect of this problem. Nevertheless, it is interesting to see these two suggestions together. If the total atmospheric resistance changes, the Earth-ionosphere potential difference will also change even while the global thunderstorm activity remained the same. The purpose of this paper is not to investigate these and other relationships. I mention them here because they demonstrate the complexity of the tasks ahead.

Establishment of a "global lightning index" and of a "global atmospheric electricity index" has also been discussed and will remain of central interest.

Existing Institution

Atmospheric Electricity at the Main Geophysical Observatory St. Petersburg. The A.I. Voeikov Main Geophysical Observatory (MGO) in St. Petersburg, under the former U.S.S.R. State Committee for Hydrometeorology, was founded in April 1849 on the basis of regular instrumental meteorological measurements. The Academy of Sciences in St. Petersburg started the measurements on December 1, 1725. There are about 30 "Doctors" and 150 "Candidates" on the staff of the MGO, among them were several members of the former U.S.S.R. Academy of Sciences[3]. Among its 12 basic departments, one is for atmospheric electricity with about nine scientists. There is a meteorological library of more than 400,000 volumes. A high level of publications is maintained. In the 18 years preceding 1976, 306 volumes of the MGO's own proceedings, 91 monographs, 33 conference proceedings, 6 atlases, 23 reference books, and about 40 types of technical literature were published. More information is to be found in Borisenkov (1977).

Professor Evgeniy P. Borisenkov, the director of the MGO, told us on our visit in October 1990 that many years ago when MGO had begun to collect data on atmospheric ozone, he was asked why. Then, he said that one day these data might be valuable. Well, that day came some time ago; his efforts have been vindicated. He told us this story during a discussion on collecting data from atmospheric electricity.

The science of atmospheric electricity, often treated in university courses as a rather simple scientific topic, is a complicated and little-understood field. This science is full of interesting problems, many of which can teach us some lessons to be applied in other environmental research. In the past, an impressive number of famous scientists have been interested in its questions and solutions. In recent decades, however, interest has waned and government support with it. This is so because, except for lightning research, practical applications have hardly been recognized. This is a kind of death sentence in a period in which the more immediate payoffs are more valuable. Accordingly, fewer young researchers were entering this field and some experienced researchers had to move into other fields. Thus, the so-called "fair-weather" branch of atmospheric electricity was deprived of much needed leadership. No comprehensive text book has been printed after Hans Israël's (1970, 1973). This is regrettable. We know now so much more and nowadays such a book would probably emphasize the currents more and the electric fields less, thereby changing the basic attitude.

Fortunately, for the sake of the modern global climate problems, routine collection of measuring data has been continued at one specific place, providing an unbroken record of developments over the last 3 decades (and thus spanning a period of rapid expansion of potentially damaging human activity): in St. Petersburg.

[3]According to a general opinion among scientists in the former U.S.S.R., their Doctor's degree is about equivalent to the German "Dr.habil," while their Candidate degree is comparable to the American Ph.D. If a Candidate has a business card in the English language he may call himself a doctor, but not so in the Russian version of the card.

Within the MGO framework, atmospheric electricity work in theory and experiment has had a long tradition, including a large amount of measurements from aircraft covering all specific domains of this science. The list of books and scientific papers produced by the scientists working there on atmospheric electricity, is certainly longer than that of any other related institution in Europe. The late I.M. Imyanitov is well remembered by the world community. Among the many books he wrote, the one on instruments is the still the most comprehensive one.

The World Data Centre of the World Meteorological Organization on Atmospheric Electricity

Historical Survey[4]

In 1962, the World Meteorological Organization (WMO, now an organization of the United Nations), recognized the need for the collection and publication of data from physical meteorology (WMO 1962). On July 5, 1963, the Chief of the Hydrometeorological Service, Academician E.K. Federov, decided, "In accordance with the proposal of the Soviet Geophysical Committee to entrust the Main Geophysical Observatory with the function of the Special Centre Data on the Atmospheric Electricity." The decision is incorporated in the Order of the Chief of the Hydrometeorological Service Under the Council of Ministers of the former U.S.S.R. N 125 dated August 7, 1963. During its fourth session, July 6-19, 1965, the WMO Commission for Aerology formed a working group (L. Koenigsfeld, chair) to determine which atmospheric electricity parameters have more than local interest and should therefore be collected and published centrally (WMO 1965). In 1965, the World Data Centre for Atmospheric Electricity (WDC/AE) officially began its operation within the MGO. The first monthly report was published in 1966, containing data beginning in January 1964. Publication has continued uninterrupted since; its most recent issue was in June 1989.

A short description of the WDC/AE was given by Kolokolov (1981).

The publication of the data is done in the form of monthly bilingual brochures (in English and in Russian). The standard tables for data measured at ground stations follow the atmospheric electricity tradition. For each measuring station, there is one table per month for one parameter. Horizontally represented are the hours of the day 00-24, vertically the days of the month 1-31, each block giving the average of the parameter for that hour. Thus, each table contains 24 x 31 = 744 values maximum. The number of parameters per station depends on what that station reports; that means in general, which parameter it measures. The parameters included are (in sequence of the frequency of inclusion) electric field intensity, positive and/or negative polar conductivity, air-earth current density. Some stations (for example, Helsinki and Macerata) apply the Closure of Ohm's Law for the selection of the data to be published. All also report summaries of the meteorological elements that are important for atmospheric electricity. For that purpose, there is a special system of symbols, explained in each issue. Occasionally, the WDC/AE received additional data for a month for which an issue had already been printed; then a special addition was published. This was done about 20 times.

When possible, special issues are distributed with aerological atmospheric electricity data from aircraft or radiosonde measurements. Eleven such issues exist from 1964 to 1975, the last one reporting Japanese aerological data.

What do these tables actually present? Ten stations provided monthly data for more than 20 successive years, one more station for more than 10. The reports are distributed to about 25 addresses in the former U.S.S.R. and 50 outside. At present, data are submitted from the following stations:

- The former U.S.S.R.: Dusheti, Irkutsk, Kara-Dag, St. Petersburg (Voeikovo), Odessa, Sverdlovsk (Verkhnee Dubrovo), Tashkent, South-Sakhalinsk (8 stations)
- Other countries: Helsinki, Finland; Swider, Poland; Macerata, Italy; Lisboa, Portugal (4 stations).

There are other potential stations in Europe that instrumentally should be able to provide continuous data of this kind. Their administrators could be expected to contribute if the collection of such data is affordable and in their interest[5].

[4]The dates and sources for the historical survey and the statistical data used elsewhere in this section were kindly provided on January 31, 1991, as a private contribution from Ya.M. Shvarts of the MGO.

[5]See Appendix I.

The WDC/AE collects and examines these data and goes back to the providing stations for more information if required. For any useful data examination, the characteristics of the stations must be known. The WDC/AE has descriptions from the following stations:

- The former U.S.S.R.: Borispol, Dusheti, Irkutsk, Kara-Dag, St. Petersburg (Voeikovo), Murmansk, Odessa, Sverdlovsk (Verkhnee Dubrovo), Tashkent, South-Sakhalinsk
- Other countries: Helsinki (Finland); Swider (Poland); Macerata (Italy); Lisboa and Porto (Portugal); Kew, Lerwick, and Eskdalemuir (U.K.); Dourbes (Belgium); Athens (Greece).

I do not know the scope and organization of these descriptions. Rather stringent requirements must be developed for application of the data for global change monitoring.

Five stations have provided for at least 1 year hourly data on all three basic parameters (electric field, both polar conductivities, and air-earth current density), so that the closure of Ohm's Law could be tested.

Extensive scientific evaluation of the collected data has taken place. There are now 33 papers essentially based on the WDC/AE data (all but three in Russian), and 26 additional papers using data from the WDC/AE extensively (all in Russian). Also, it is estimated that about 10 additional papers used some data from the WDC/AE, but there is no list.

As indicated above, any substantial evaluation of the existing and future data for global change monitoring depends on the availability of the data in a computer-usable form. That was not the case with the monthly reports published so far. The WDC/AE has begun to convert all the data from the tables; i.e., from 1964 on, into digits on magnetic tape or diskettes. At present, we do not have an estimate on the completion date for this job. For the future, a system should be found by which providing stations submit their data in a form directly usable by the computers in the WDC/AE. This will require agreements on standards. The station in St. Petersburg is already automated to a certain degree and that effort continues. One goal would be to have the output on 5.25-inch diskettes in ASCII form.

Below, I will present a more detailed discussion on this essential effort to use parameters from the atmospheric electricity global circuit for the monitoring of global change status and processes. An effective program, dedicated scientists, and much work will be required. The program is the best evaluation of the data already collected, and those to be collected, and as one way to produce a tool as soon as possible for the acquisition of needed environmental information.

Potential of a World Data Centre for Atmospheric Electricity[6]

A Question of "Raison d'être." In Garmisch-Partenkirchen 1974, Derek R. Lane-Smith voiced concern about the significance of atmospheric electricity data beyond their local validity (Lane-Smith 1977). That was not the first time such doubts have been heard. Ralph Markson in Uppsala, Sweden, (1988), presented facts and factors that indeed support Lane-Smith's statement.

These opinions obviously contradict the findings of the WMO Commission for Aerology (Louis Koenigsfeld, chair) on July 19, 1965 (WMO 1965). A WDC/AE could hardly be justified if the concerns indicated in the previous paragraph would indeed be fully true. A strong factor for a conclusion that those concerns are not fully valid, is given by the existence of the Carnegie curves and by Paramonov's analysis (1950). Dolezalek's critique of the classical picture of atmospheric electricity (1972), sometimes misinterpreted as an attempt to discredit it, was not so intended. The paper on results from the WDC/AE that Shchukin et al. presented in Uppsala, Sweden (1988), supports a conclusion that there are good reasons for WDC/AE's work. At the Uppsala conference, there were additional papers that deal with closely related problems (e.g., Tammet 1988b). It is expected that at least some of the 33 papers (mentioned above) based on data from the WDC/AE may also support the conclusion on the usefulness of the WDC/AE; they are mostly unknown because of the language barrier. I am afraid, however, that neither they nor the one by Shchukin et al. will specifically respond to the critiques of Lane-Smith and Markson mentioned above. To this end, other efforts will be necessary, and I will discuss them below.

[6] In our present discussion, we leave out the measurement and data handling of the "Maxwellian Current"; i.e., the sum of the densities of the conduction and displacement currents. This is potentially a very important parameter (see Ruhnke et al 1983), but the time resolution of data acquisition, handling, storage, and distribution is so different from the practice applied in the present WDC/AE that an inclusion (1) would be very extensive, and (2) not directly influence the data collection as it exists and is to be continued.

Defined Indices and Databases. As central elements of the atmospheric electricity global circuit, we consider the global thunderstorm activity and the potential difference between the ionosphere (more exactly, the atmospheric electricity equalizing layer) and ground. These two elements are to be assessed in the form of a "global lightning index" for the thunderstorm activity, and a "global atmospheric electricity index" for the earth-ionosphere potential difference in moderate latitudes. According to the classical picture of atmospheric electricity, there is a direct (but not necessarily linear) connection between these two indices. So far, we do not know their relationship in quantitative terms nor which alien factors may interfere, and therefore must establish these two separate indices. For the remainder of this document, I leave the "global lightning index" aside so that it can be discussed elsewhere.

In addition to these central elements, we are also interested in the development of local situations over time. The conductivity and the content of the various types of ions are our main concern. This is why we group them and potentially others under the term "local air electricity database" for any given station.

Parameters and Data for Ground Stations

Parameters of Interest. For the establishment of a "global atmospheric electricity index" and of a "local air electricity database," four groups of parameters are of interest.

1. Air-earth conduction current density
2. Electric field
3. Positive polar conductivity
4. Negative polar conductivity.

Supporting parameters are:

- Closure of Ohm's Law
- Ion number mobility spectrum or its constituents such as ion number densities, including cluster ions, condensed ions, and aerosol ions
- Space charge densities.

Environmental Parameters Are General or Specific Meteorological Elements. General elements are essential for all atmospheric electricity ground measurements such as absolute humidity (water vapor pressure), air temperature, precipitation, wind velocity, aerosol spectrum, cloudiness, general local brightness, atmospheric stability aloft, air turbulences. Specific elements are those that are essential for a given station such as wind direction, ion sources, space charge sources, aerosol sources. Although desirable otherwise, there will probably be only a few stations that cover all the parameters listed here, but even stations that cover only one will not necessarily be excluded from our interest. This seems to be the actual situation that will determine the WDC/AE coverage of parameters.

Availability and Reliability of Own and Alien Historical Data. The historical data of the WDC/AE from January 1964 are available there. It cannot be expected that the selection of a measuring site, the selection of the parameters and marginal data to be recorded, and the applied care for accuracy, precision, and reliability have been optimum for modern global-climate investigation requirements. There are two performances to improve the chance to obtain useful modern knowledge in spite of such shortcomings. One is to start collecting additional information from the stations from which the data have been collected. The other is a careful investigation in which manner the collected data could be made indirectly usable for modern purposes. For the first procedure, all stations having, at any given time, provided significant data to the WDC, might be asked to provide extensive station descriptions and also station histories unless they have already done so. In *Suggested Requirements for Station Descriptions and Histories*[7], we submit points for such station descriptions and histories. For the second performance, we distinguish between aiming at global or regional information. For both, it might be useful to consider several stations at once. Which missing parameters can be approximated by a combination of other available parameters? Which shortcomings in accuracy might be overcome by using a large statistical population? Is it possible to recognize and then eliminate significant bias? How can the optimum individual data be selected for a meaningful averaging (for example: is it, for a given station, practical to use only night values because at that station day values had been more heavily disturbed; or, should hours with certain wind directions be excluded?). Are absolute values or variations more meaningful for averaging in certain cases? Here, these few examples may be sufficient. Obviously, many more similar considerations will be needed to make optimum use of older data.

For the availability of alien historic data, an investigation could be made where such data are still kept. The Carnegie Institution in Washington, D.C., is one such place; others may be the observatories in Kew (records now in the library at Bracknell) and in Potsdam. Large libraries may still have collections of *in extenso* data (MGO's library is one candidate; the U.S. Naval Research Laboratory, Washington, D.C., may be another). Books may contain tables of data or indications of other sources[8].

[7] See Appendix II.

[8] For a discussion of this problem see Appendix III.

Digitalization of Data. Evidently, (see, among others, Tammet 1988, p. 31) data collected only in the form of printed tables cannot be analyzed to the necessary degree because their manual evaluation would be too expensive. Therefore, it is highly desirable that all previous and new data should be digitized and become available in a form useful for computer evaluation. The scientific community can be grateful that this is being done in St. Petersburg for the WDC/AE data. Further economizing of the collection and use of data could be achieved if the stations would provide these data to the WDC in a computerized form. To do this, certain minimum standards must be agreed on that are binding for all stations. Because many, if not most, stations already store their own data in a computer-compatible form, such standardization could be made more easy, respectively, more complicated.

Standardization. An agreement on standardization should be reached as soon as possible, led by the WDC/AE with participation by the data-providing stations and scientists interested in using the data. Some preparatory work is needed. An *ad-hoc* suggestion would be to use 5.25-inch diskettes and ASCII format (including abbreviations for the meteorological parameters; each diskette would contain information about how it is to be used). Moreover, it might be advisable to learn how other WMO data centers are handling this, and to follow their example as much as possible. Many potential users will have worked with data from other centers. In April 1991, H. Tammet (personal contribution) already produced the basics and the beginning of such an effort. A workshop to prepare such an agreement might be held very soon, with the goal that the final agreement can be resolved during the Ninth International Conference on Atmospheric Electricity in 1992. Probably the initial initiative for a workshop should come from the WDC. The Office of Naval Research European Office may be able to assist with workshop financing. There may be several other standardization necessities. The standardization of station descriptions should be rather easy (see Appendix II on suggested requirements for station descriptions and histories). Information must be available about the meteorological and electrical climate of the station, measuring methods, kinds and placements of the antennae, and instruments used for data acquisition and handling. This could be a possible additional workshop topic. Much more difficult would be creating the necessary agreement on the types of instruments, their performance, and (a topic of special difficulty in atmospheric electricity) the selection of useful data. The complexity of this problem and some ideas for a somewhat different procedure are outlined elsewhere[9].

Parameters and Data for Aerological Measurements

Here, all the possibilities and proposals for measuring the "ionospheric potential" from instruments carried aloft, should be included; i.e., radiosondes, captive balloons and aircraft, maybe even kites. The WDC/AE could work with Dr. Ralph Markson to draft a system analogous to the one discussed above for ground-station data (e.g., the station description is replaced by an aircraft description). An important question arises. Is it possible to make all suitable data available to the WDC/AE acquired by aircraft instrumented for atmospheric electricity?

Concluding Statements

Wider Publication of Past Scientific Results. To make the work of the existing WDC/AE more generally known and to stimulate more participation in cooperative possibilities from countries outside of the former U.S.S.R., it is desirable to distribute knowledge on scientific results obtained with the help of the WDC/AE. Except for only 3, the 33 + 26 scientific reports mentioned above are all in Russian. While it would be unrealistic to attempt to get them all translated into English, French, or German, somebody in St. Petersburg might be willing to write one or several summary reports on the results contained in these 59 papers. Such a summary report could be published; e.g., in *Meteorology and Atmospheric Physics*, together with the full and updated paper by Shchukin et al. (1988). Reprints can then be distributed to interested institutions.

The Central Role of the WDC/AE. If the tasks of a WDC/AE are to be conducted with expertise, energy, motivation, and flexibility, it is necessary that the scientists involved are (and remain) researchers and do not become data administrators only. The WDC/AE cannot help but become the leading institution for the establishment and further development of the methods to be applied by the recording stations that produce the data. Looking at the example established by Imyanitov, the Atmospheric Electricity Group at the MGO should be able to fulfill these obligations.

Following is a possible outline of their work:

- Define the kind of results to be produced by WDC/AE that would be most beneficial for the promotion of related research and/or for practical applications
- Determine how the WDC/AE could produce these results with the required reliability and accuracy, including the necessities for the measuring stations providing the data

[9] See Appendix IV.

- Find, define, and (when appropriate) make known the shortcomings that impede the provision of adequate data; i.e., data that meet the requirements for the theoretical understanding of atmospheric electricity and/or for its measuring techniques
- Regarding global change monitoring approach 1 (see page 2): find a secure basis upon which still unknown theory should be developed; investigate earlier attempts to solve the problems; circumscribe these problems as accurately as possible (set out to solve them or bring them up for discussion at conferences or in the literature)
- Regarding global change monitoring approach 2 (see page 2): define the parameters for which the techniques must be improved; list the sequence of their potential for improvement and of urgency
- Determine which of approaches 1 and 2 can be done by the MGO; try to find other agencies for the rest; do the necessary and possible experiments.

A careful theoretical study, based on many older considerations and hypotheses, is needed. Focus would be to find out under which conditions the global and local shares in the measurement of the air-earth conduction current density can be separated from each other, using one or several stations.

To successfully approach the tasks involving measuring techniques, it may turn out to be desirable that the WDC/AE should install, and run within the MGO, a pioneer station for atmospheric electricity global circuit measurements. To this end, the problem of the correct measurement of the air-earth conduction current density should be attacked by a series of experiments at a suited location. The most important and urgent measurement problem is the execution and conclusion of an investigation of the classical methods to record the conduction current density, to evaluate modern proposals for a different system, and to learn how to relate them to each other in quantitative terms. Suggestions are given in a special document[10].

We are trying to look at the research problems existing in this area from a global point of view. We are well aware that within the 20th century many excellent scientific efforts have been executed with good, but only partial results. We think that none of them could be carried through on a sufficient scale and long enough to produce the necessary solid result. Now, there does not seem to be any incentive for brilliant young scientists to enter this field. This is unfortunate because we know that this domain is full of exciting challenges and rewards.

The MGO has accepted the task to run the WDC/AE, wants to do it right, and to the best benefit of the scientific community and all mankind. We should acknowledge that no other place exists that could do the work better than the MGO. Other stations have done much of the work already. I refer to the work done at Buchau, Aachen, and elsewhere under the leadership of Hans Israël, the work at Naval Research Laboratory, Bhartendu's work in Canada, and others. None was based on MGO's tradition, and nearly all of them stopped working long ago. One exception is Reinhold Reiter. His new book (Reiter, 1992) promises to provide many data urgently needed for the purposes indicated in this paper. The MGO has an ideal location for the field experiments, its staff is large enough, and it is led by scientists motivated to do basic research of quality.

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[10] See Appendix V.

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List of International Atmospheric Electricity Conferences and Their Proceedings

- **First Conference**: May 19-21, 1954, Wentworth-by-the-Sea near Portsmouth, New Hampshire; 57 participants from 10 countries; 29 papers presented. The proceedings include the discussions, picture of participants with names, list of participants.
  Proceedings: Holzer, Robert E. and Waldo E. Smith (eds.), Proceedings on the Conference on Atmospheric Electricity. Geophysical Research Papers No. 42, AFCRC-TR-55-222 IV + 247 pp. Geophysics Research Directorate, Air Force Cambridge Research Center, Bedford, Massachusetts, 1955.
- **Second Conference**, May 20-23, 1963, Portsmouth, New Hampshire; 91 participants from 10 countries; 59 papers presented. The proceedings include discussions, author index (not including authors of references), picture of participants with names, list of participants.
  Proceedings: L.G. Smith (ed.): Recent Advances in Atmospheric Electricity. Pergamon Press, London, 2958. XV + 631 pp.
- **Third Conference**, May 5-10, 1963, Montreux, Switzerland. 178 participants from 26 countries; 66 papers presented. The proceedings include the discussions, a subject index of 18 pages, an author index not including the authors of references, picture of participants without names.
  Proceedings: S.C. Coroniti (ed.), Atmospheric and Space Electricity. Elsevier, Amsterdam, 1965. XIV + 616 pp.

- **Fourth Conference**: May 13-18, 1968, Tokyo, Japan. 98 participants from 16 countries; 92 papers presented. The proceedings include the discussions, subject index of 7 pages, picture of participants with names.
  Proceedings: Samuel C. Coroniti and James Hughes (eds.): Planetary Electrodynamics, 2 volumes. Gordon and Breach, New York, etc., 1969. Vol. 1: XX + 587 pp.; vol. 2: XX + 503 pp.
- **Fifth Conference**: September 2-7, 1974. Garmisch-Partenkirchen, Federal Republic of Germany. 196 participants from 26 countries. 115 papers presented, one scientific address, 9 general discussions conducted. The proceedings include the discussions after the papers and general discussions, a subject index of 32 pp. an author index including the authors of references of 12 pp., an index of observation localities of 4 pp., an index of chemical symbols, and a report on preparation and conduct of the conference. Picture of participants without names.
  Proceedings: Hans Dolezalek and Reinhold Reiter (eds.): Electrical Processes in Atmospheres. Steinkopff, Darmstadt, 1977, XVII + 865 pp.
- **Sixth Conference**: July 18 - August 1, 1980, Manchester, England. More than 104 papers presented. Number of participants unknown. The proceedings include a subject index of 4 pages and a list of contributors (of articles to the proceedings, with addresses) of 8 pages.
  Proceedings: Lothar H. Ruhnke and John Latham (eds.): Proceedings in Atmospheric Electricity. A. Deepak, Hampton, Virginia, 1983. XIII + 427 pp.
- **Seventh Conference**: June 3-8, 1984, Albany, New York. Number of participants unknown. 132 papers presented. The proceedings represent the preprints to the conference. They include an author index of 3 pages.
  Proceedings: Richard Orville (ed.): VII International Conference on Atmospheric Electricity. American Meteorological Society, Boston, Massachusetts, no year indicated.
- **Eighth Conference**: June 13-16, 1988, Uppsala, Sweden. Number of participants: 164 from 24 countries. 154 papers presented. The proceedings I include an author index of 4 pages.
  Proceedings I: S. Lundquist (ed.): Proceedings, 8th International Conference on Atmospheric Electricity 1988. Institute of High Voltage Research, Uppsala University, 1988. 897 pp.
  Proceedings II (a selection of papers only): John C. Willet and James E. Dye (eds.): Selected Papers on Atmospheric Electricity. American Geophysical Union 1989, reprinted from the Journal of Geophysical Res. 94:D11:13., 083-13, 337. 254 pp.
- **Ninth Conference**: Planned for 15 - 22 June 1992 in St. Petersburg, Russia; upon invitation from the Russian Academy of Sciences, Scientific Center St. Petersburg. For more information contact the President of the International Commission on Atmospheric Electricity: Dr. Lothar H. Ruhnke, 11208 Wedge Drive, Reston, Virginia, 22070, USA. Telephone at office: +1 (202) 767-2951, at home +1 (703) 471-1978; Telefax: +1 (202) 767-9130; Telemail OMNET: ATM.PHYS.NRL.

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Point of Contact: Dr. Ya M. Shvarts

Appendix I.	Atmospheric Electricity Global Circuit Stations in Europe
Appendix II.	Suggested Requirements for Station Descriptions and Histories
Appendix III.	Discussion on Evaluation of Secular Trends in Atmospheric Electricity
Appendix IV.	Discussion on Data Selection (the "fair-weather syndrome")
Appendix V.	Suggestions for a Pioneer Station on Global Circuit Atmospheric Electricity Measurements Centered at World Data Centre/Atmospheric Electricity

Appendix I

Notes About Atmospheric Electricity Global Circuit Stations in Europe

1. **Atmospheric Electricity Stations in (Western) Europe that recorded global circuit elements after WW II (compiled from memory, incomplete).**

   *1991-still in operation

   Sweden: o Uppsala*
   Finland: o Helsinki*
   o Kevo*
   U.K.: o Eskdalemuir
   o Kew
   o Lerwick

   West Germany and Swiss Stations Operated from FRG
   Group led by H. Israel

   o Aachen
   o Buchau
   o Freiburg
   o Königstuhl
   o Nürburg
   o Payerne
   o El Salvador (San Salvador)
   o Brissago (Isole di)
   o Gornergrat
   o Jungfraujoch-Sphinx
   o Jungfraujoch-Institute
   o Luino
   o Sonnblick

   Group led by R. Mühleisen

   o Weissenau*
   (plus expeditions on oceans)

   Group led by R. Reiter

   o Garmisch-Partenkirchen FhG-Institut
   o Garmisch-Partenkirchen Skistadion
   o Garmisch-Partenkirchen Farchant
   o Garmisch-Partenkirchen Müllerstrasse*
   o Garmisch-Partenkirchen Wank*
   o Zugspitze
   o Zugspitzbahn

   Belgium

   o Uccle
   o Dourbes
   o Ardennes (exact name unknown)

   Switzerland

   o Aarau
   o Payerne

   Portugal

   o Lisboa*
   o Porto

   Italy

   o Macerata*
   o Venezia

   Greece

   o Athens*

   Note for stations in Eastern Europe refer to list mentioned in main text (p. 4.6)

2. **Stations or Potential Stations in the same area for which the World Data Center for Atmospheric Electricity in St. Petersburg does not have a station description and from which they do not get data.**

   Active

   Garmisch-Partenkirchen, Müllerstrasse, and Wank, FRG

   Address

   Dr. Reinhold Reiter
   Fritz Müller Straße 54
   D-8100 Garmisch-Partenkirchen
   Federal Republic of Germany
   Telephone: +49 (08821) 57445
   Telefax: +49 (08821) 52382

   Approximate location

   47.30°N, 11.05°E
   Wank: 1780 m aSL
   Müllerstraße: 740 m aSL

   Recorded parameters

   Wank mountain peak

   Atmospheric electricity field: radioactive collector, simultaneously with high and with low sensitivities
   Current density: Wilson plate antenna, with high and low sensitivities simultaneously
   Air conductivity: positive polar only
   Temperature
   Relative humidity
   Wind velocity
   Sky brightness
   Precipitation.

   Müllerstraße

   Atmospheric electricity field: radioactive collector & field mill
   Current density: wire antenna & Wilson plate antenna
   Air conductivities: + & -
   Cluster ion densities: + & - (in preparation)
   Point discharge current
   Precipitation current density
   Temperature
   Relative humidity
   Absolute solar radiation
   Sky brightness
   Precipitation rate and amount
   Wind velocity
   Aitken nucleus number density.

   Data processing

   Automatic data processing on Wank peak with variable time resolution up to 1 value/second, based on high-precision timing (controlled by Physikalisch-Technische Bundesanstalt). Data transmission from Wank to Müllerstraße by telecommunication. Storage on computer hard disk. Variable data processing.

Research objectives

Special investigations on relationships between atmospheric electricity and weather under consideration of the height difference between the two stations (about 1.1 km). Studies in solar/terrestrial relationships mainly on Wank peak. Solar-geophysical data from URSI/Darmstadt, FRG, are continuously available via BTX communication.

Active

Weissenau/Ravensburg, Germany (list incomplete)

Address

Dr. Hans Hofmann
Astronomisches Institut d.Universität Tübingen,
Aussenstelle Weissenau
Rasthalde
D-7980 Ravensburg-Weißenau, FRG
Telephone: +44 (0751) 61-321

Approximate location

47.50°N, 9.32°E
estimated 400 m aSL

Recorded parameters

Atmospheric electricity field
Air conductivity: + & -

Data processing

Recordings of last 5 years evaluated research activities: 10 kHz sferics, thunderstorm locations for 120 Km and 1,000 Km, lightning counts. Work is expected to continue for 2 more years, thereafter, it is uncertain.

Active

Tahkuse, Estonia

Address

University of Tartu
Air Electricity Laboratory
18 Ülikooli Street
Tartu, Estonia
Telephone: +7 (01434) 35-383
Telefax: +7 (01434) 35-440
Telex: 173243 TAUN SU

Professor Hannes Tammet
Field Station Tahkuse

Approximate location

58°N, 25°E
less than 50 m aSL

Recorded parameters

Atmospheric electricity field
The total ion regime: lightning occurrence in two ranges of distance.

Inactive

Uppsala/Marsta Observatoriet, Sweden

Address

Dr. Edgar Knudsen
Marsta Observatoriet
Meteorologiska Institutionen
Uppsala Universitet
Box 516
S-75120 Uppsala, Sweden
Telephone: Institute- +46 (018) 53-67-58
Observatory- +46 (018) 36.71.20
Telefax: +46 (018) 54-47-06
Telex: 76024 UNIVUPS S
Visitors address: Kyrkogårdsgatan 6

Approximate location

59.55°N 17.38°E, estimated 100 m aSL

Recorded parameters

This observatory did not operate for a few years; there are plans to reinstall after availability of suitable computer facilities.
Atmospheric electricity field
Air conductivities: + & -
Current density: inoperative
Space charge density
Maxwellian current by long antenna
Lightning receivers.

Presently recording

Temperature
Relative humidity
Pressure
Visibility
Windspeed and direction
Hours of sunshine
During daytime: clouds
Precipitation.

Research tasks

Theory of charge generation, acoustic propagation in the atmosphere, atmospheric electricity measuring instrumentation, theory of the "fair-weather condition," standardization in atmospheric electricity, effects of obstacles above ground, relationship wind/space charge, meteorological problems.

Inactive in recording, but possibly interested in future:

Toulouse, France

Address

Dr. Serge Chauzy
Université Paul Sabatier
118 Route de Narbonne
F-31062 Toulouse CEDEX, France
Telephone: +33 61.55.65.84
Telefax: +33 61.55.31.20

Approximate location

43.33°N, 1.24°E
estimated 500 m aSL.

Research objectives

Research activity on thunderstorm electrical problems, in particular atmospheric electric conductivity under thunderclouds. Expertise and interest for recording of global circuit elements, but at present no such possibility.

3. **Stations that provide data to the World Data Center**

Athens, Greece

National Observatory of Athens
Institute of Meteorology and Physics of the Atmospheric Environment

Address

Atmospheric Electricity Station
P.O. Box 20048
H-118 10 Athens, Greece
Telephone: +30 (1) 345-6257
Telefax: +30 (1) 342-1019
Telex: 215530 OBSA GR

Dr. D. A. Retalis

Approximate location

37° 58' 30" N, 23° 40' 15" E, 107m aSL, on the rather flat top of Nymphs Hill in the center of Athens, about 30m higher than surrounding city.

Established 1965, since 1968 measuring all main atmospheric electric fair-weather parameters.

Field, air-earth current density, polar conductivities, small and large ion number densities. Average closure of Ohm's Law varies from 1.1 in May to 2.1 in December; annual value-1.4. Annual mean of thunderstorm days averaged over 80 years-18.

Meteorological parameters (air temperature, relative humidity, wind speed) plus smoke (filter method) and sulfur dioxide (titration) are recorded.

Planned additions: Ground-flash lightning location system, disturbed weather atmospheric electric parameters, recording of Maxwell current density.

Still missing: automation of measuring systems.

Helsinki, Finland

Address

Finnish Meteorological Institute
Department of Geophysics
P.O. Box 503
SF-00101 Helsinki, Finland
Telephone: +358 (0) 1929-513; switchbd: 1929-1
Telefax: +358 (0) 1929-539

Dr. Tapio J. Tuomi

Location

Helsinki-Vantaa Airport, 17 Km north of Helsinki center.

Approximate location

60° 19' 32" N
24° 57' 55" E
53 m aSL

Recorded parameters (since 1977)

Electric field (radioactive collector)
Air-earth current density (horizontal plate) (both in large horizontal grid ca. 1 m above ground)
Positive & negative conductivity (Gerdien 1.3 m above ground) visibility, other meteorological parameters.

Kevo, Finland

Address, telephone, scientist in charge same as in Helsinki

Location

69° 45' 19" N
27° 00' 48" E
94 m aSL

Recorded parameters (since 1980)

Electric field (radioactive collector)
Air-earth current density (horizontal plate) both on horizontal grid about 1 m above ground.

These two stations may be replaced by a new one in Finland.

Macerata, Italy

Address

Osservatorio Geofisico Sperimentale
Viale Indipendenza 180
I-62100 Macerata, Italy
Telephone: +39 (0733) 30-743
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Professor Alfredo Murri

Location

43° 17' 32" N
13° 25' 09" E
299 m aSL

Measured/recorded parameters

Electric field (since 1956), radioactive collector
Air-earth current density (since 1980), horizontal grid plate both polar conductivities (since 1974), Gerdien, closure of Ohm's Law
Atmospheric radioactivity (since 1979), Geiger counter
Thunderstorm frequency per hour
Temperature
Relative humidity
Water vapor pressure
Wind direction and velocity
Visibility
Global radiation
Precipitation
Evaporation
Cloudiness.

Note: for stations in the former U.S.S.R. see main text (p. 4-6)

Swider, Poland

Address

Polish Academy of Sciences
Institute of Geophysics
ul. Ks. Janusza 64
PL-01-452 Warzawa, Poland
Telephone: +48 (22) 36.44.40 or 37.05.22
Telefax: +48 (22) 37.05.22
Telex: 817582 pl

Dr. Stanislaw Michnowski

Location

Atmospheric Electricity Station at Swider near Otwock

Approximate location

52.07°N
21.16°E

Recorded parameters

Atmospheric electricity field, collector method, time constant 6 s
Both polar conductivities, time constants 2 min
Air-Earth current density, horizontal plate, time const. 500 sec.

Measured parameters

Aerosol particle number densities in range 5 nm to 10μm, three measurements per day, standard time
Measurement of the 2-weeks average of radioactive Nuclei, filter method
Daily concentration of sulfur dioxide, nitric oxides, dust in atmosphere, radioactivity in precipitation.

Meteorological Parameters

Temperature
Relative humidity
Water vapor pressure
Direction of wind
Velocity of wind
Atmospheric pressure
Precipitation
Cloudiness, degree, and type
Others.

Note: for stations in the former U.S.S.R. see main text (p. 4-5).

Appendix II

Points for Station Descriptions and Histories

Introduction

The station description can be a depository of information about those elements around, at, and inside a station recording atmospheric electricity parameters that have or might have an influence on the values and variations of these parameters. The station history records if, when, and how these elements change over time. This depository

- Allows any user of the recorded data get criteria for the quality and reliability of the data and their features responding to environmental changes; it may provide clues for any specialty in the data otherwise difficult to explain
- Allows the scientists running that station to control now (or in retrospect) the maintenance and/or deliberate or inadvertent change of the situation; it may alert them to signs that some significant element is varying.

The following elements might be considered for inclusion:

- Date of this description
- Date of previous description
- Station name, address, telephone, and electronic mail connection; administrative affiliation, name, and title of head of station, and names of scientists working there
- Longitude, latitude (to seconds), height in m aSL.

Environment-Ground

Information should be provided about physical geography, orography, land cover, type of soil and deeper ground, hydrology, ground climatology such as seasonal variations of elements like

- Snow cover
- For stations near a shore, waves, wave breaking, white caps, water surface description of kind of shore and of geographic (including height) situation related to station and of ground between shore and station
- For stations leeward of high mountains, existence of events such as floating snow crystals from drifting snow.

Other specialties as determined by the scientists at the station; e.g., large waterfalls.

Environment-Atmosphere

Information should be provided about climatology quoting average values per month, including variations of significant magnitude of the following elements:

- Air, soil, and water temperature if there is water nearby, absolute humidity (vapor pressure)
- Wet bulb temperature
- Wind direction and velocity; events of gustiness
- Hours of sunshine
- Cloudiness
- Precipitation (form and amount per form)
- Aerosol content (estimate compared to other areas)
- Special events such as significant seasonal processes, monsoons, harmattans, other special wind systems (foehns, scirocco, bora, mistral, Santa Ana, katabaric).

Anthropogenic Disturbances

This category includes information about

- Economical geography, sources of pollution and of space charge and/or radioactivity (source, direction and distance from station, amount of output observed or anticipated, influence on atmospheric electric parameters)
- Human habitat, industry, farm operations in the area with distances and directions (related to prevailing wind direction)
- High-voltage electric power lines, voltage (ac or dc), distance, and direction
- Transmitters for electromagnetic waves, kind, height, distance, and direction.

Station and Surrounding Area

A scaled map should be provided showing locations of antennae, houses, or other disturbances of the electric field (include height), streets (kind of street surface and traffic burden). Because of the problems of short-distance variation of atmospheric electric elements, problems of distorting the electric field by structures, and obsturbances by pollution, such maps are in many cases the most important part of a station description.

Measuring Instrumentation fo. each Atmospheric Electricity Parameter

Information should be provided about

- Method, description of antenna, placement of antenna with indication of field-disturbing items near it, elevated or flush with ground, resistance between antenna and ground where appropriate, indicate whether (by feed-back circuits) the electric potential of an antenna is maintained at ground level or not
- Type of recording of values, recording intervals, method of averaging, time constant of measurement and time constant of recording, method of zero determination, determination of drift
- Method of calibration, data handling, data storage
- Special recording of thunderstorms in the neighborhood
- Special precaution to filter out disturbances (for example, electromagnetic radiation from nearby transmitters).

If instruments were purchased, indicate the vendor or deliverer and type of instrument; otherwise, quote sources of information (e.g. paper in a journal) where described.

Measuring instrumentation for environmental parameters (each separately described) should include placement, protection against unwanted disturbances, exposition to free environment, type of recording. Beginning and ending of precipitation and fog should be recorded. With regard to source of instruments, give the information as requested at end of preceding paragraph.

If recording instruments were chosen to determine the criteria for the selection of data (see next paragraph), describe them and the method used.

Selection of Data

Which criteria are applied to select which hours with data provided meaningful values? Possibilities are

1. One selection with hours during which the closure of Ohm's Law was always between which limits
2. One selection with "fair-weather hours" only
3. One selection with all hours without precipitation only
4. One selection with all hours for which the variation of data was under a certain limit
5. Data selected only if any of the above (which one?) applied for at least 3 successive hours
6. Combinations of numbers 1 through 5
7. All data without consideration of meteorological conditions.

For any of these methods, criteria for the selection should be given. For example for item 2, the criteria could be: no precipitation, no fog, cloudiness under 3/10 and not concentrated in the zenith, wind under 3 Beaufort; indicate which criteria were selected. For a more detailed discussion, see Appendix IV.

Recording Time

For all recordings, use the same GMT, UT, or Z time, local legal time (if so, give relation to GMT and state if summer time or daylight saving time applies and which one and [if possible, when]), local sun time.

Other Sources of Environmental Information

State existence of official weather or climate stations in the neighborhood of the station; private, school, or business-owned stations of this type (accessible); recording stations for radioactivity, and air pollution.

Additional Information

With station administration concurrence, information on atmospheric electricity research performed or planned at that station would be welcome, including a list of publications. Also, names might be included of persons who might give more information (e.g., scientists working at the station in the past). Periodically, the information could be updated.

An opinion about the station written by a researcher would be valuable; e.g., the work performed there, how things could be improved, which risks exist for the future. A critical assessment by a scientist would be welcome. Possible information could be

- Is there indication on the constancy or variability of the local columnar resistance during the selected hours (see selection of data)
- Is it assumed that local generators (e.g. austausch generator) significantly influenced the measurement of the air-earth current density
- How does the researcher consider the representativity of the data
- Have there been any special studies conducted concerning this problem
- How closely are the variations of the air-earth current density (whether directly or indirectly measured) to follow the Carnegie curve or other curves of the same kind
- Is there reason to recommend using only data from the station that is especially selected for defined reasons (e.g., only night values, no hours with sea-land breeze)
- Is there indication that in the past, the operation of the station encountered significant and relevant problems?

Station History

In the station description, indicate how significant changes in the information will be documented and conveyed. Include statements about important factors that will remain through all updating and expanded when necessary. In this way, a continuing history of the station is created. Sufficient and clear data should be included that may be valuable when that station's data is applied for future tasks.

Appendix III

Discussion 2nd Evaluation of Secular Trends in Atmospheric Electricity

Problems and Survey

Changing human attitudes, behavior, and activities would involve large amounts of manpower and finances. These changes may be seen as necessary because it is feared that human disturbances of the natural equilibrium may become globally significant. Because of the scale of such efforts, the possibilities to get more reliable information are economic in a true sense. Often, it has been stated that decades of more measurements will be needed before we can assess the existence, size, and danger of anthropogenous global climate changes. If we were able to extend the period of information backwards by several decades, this time (during which irreparable damage could occur because of ignorance) could be reduced. Because they have never been carefully investigated with such a purpose in mind, we are not certain how much previous atmospheric electricity measurements can provide useful information. Before we can decide whether an effort in this direction is worthwhile, we should try to line out a framework for such potential investigations; hence, the objective of this appendix.

Seen from our present state of knowledge and our present priorities of interest, the following atmospheric electricity elements should be investigated. Are they are changing over time? If so, how and why?

- Thunderstorm nature, frequency, and geographic distribution; first, assess secular changes in the number of thunderstorms and/or of lightnings
- Ionosphere/Earth potential difference; assess its potential secular change by direct or indirect measurements of air/earth current density at ground or in the air
- Atmospheric electrical conductivity and its secular changes at a selection of typical stations of various local atmospheric and geographic conditions and of types of anthropogenous influence.

The essential tools for such investigations are historical data. Unfortunately, much original data have been lost. Others are still available; they should be digitized. In the cases of lost data, old publications with original data evaluations are often available. The number of such sources, as well as the variety of conditions and the spread of geographical locations dealt with, are indeed very large--much larger than many of our contemporaries may assume.

Any useful evaluation of secular trends encounters two large obstacles which both may include difficult scientific problems:

1. Atmospheric electricity research has, with a few exceptions (see next section below), never been interested in secular trends. Investigations had different objectives. Therefore, the selection and duration periods of measurements is not *a priori* favorable for secular research topics.
2. Reliability and accuracy of measuring methods will often be disappointing. They require careful evaluation of the still-existing possibilities, their limitations, and possible bias. In some other cases, high standard of accuracy and reliability will be found. Sometimes, the care applied to these older measurements surpasses the care usually applied nowadays when modern methods seem to facilitate the measuring tasks.

In addition to the traditional methods of atmospheric electricity, sophisticated methods developed for finding weak signals in a high noise level may have to be adapted to these particular purposes. If our general knowledge of the problem of measuring atmospheric electricity data can be improved (e.g., by the work of a pioneer station as discussed in Appendix V), we may also gain more tools for the *post facto* evaluation of older measurements.

In the main text of this document (*Availability and Reliability of Own and Alien Historical Data*), several related issues were mentioned. They are repeated here:

"..it might be useful to consider several stations at once. Which missing parameters can be approximated by a combination of other, available, parameters? Which shortcomings in accuracy might be overcome by using a large statistical population? Is it possible to recognize and then eliminate significant bias? How can the optimum individual data be selected for a meaningful averaging (for example, is it practical, for a given station, to use only night values because at that station day values had been more heavily disturbed; or, should hours with certain wind directions be excluded?). Are absolute values or variations more meaningful for averaging in certain cases?"

There are more questions of this kind. A good station description may help to find answers for a few of them (e.g., investigating the influence of sea-land breeze for a station near a rocky ocean coast with breaking waves predominating; or identifying the presence of snow drifting from a nearby high mountain). The influence of these and other elements has been a main topic for numerous atmospheric electricity studies in the past. Can we try to turn around what has been learned by them?

Earlier Attempts To Investigate A Secular Change

As indicated above, investigating truly secular variations of atmospheric electricity parameters was not a priority before about 1960. Extended measurements of these parameters have been made, including periods of 10 or more years of incessant recordings. Even then, it seems that one important part of the prevailing interest was to look for an influence from the solar 11-year period rather than to check whether these elements undergo a long-period trend. The interest in the sun-spot circle influence appeared early (see e.g., Bauer [1926] or his figure on page 355 of Israël [1973] which depicts measurements from 1902 to 1922).

Extended continuous measurements are known from Watheroo, West Australia 1924-1934-1945 (Wait 1937, Wait, and Torreson 1941; Wait 1942); Tucson, Arizona 1933-1950 (Wait 1948, Hogg 1955); Huancayo, Peru 1924-1934-1945 (Wait and Torreson 1948); Figure 249 on page 493 in Israël (1973) and Figure 3 on page 89 of Hogg (1955) display data from these stations. They are extended until 1945 although the origin of the data for 1934 to 1945 is not referred to in the papers by Wait, and Wait and Torreson (up to 1942). This needs some clarification.

Two examples of a discussion of secular changes with some analogy to our present interest are

1. Observations at Davos, Switzerland
2. Observations over the Atlantic Ocean (the latter originating with the Carnegie cruises).

The Davos case is of special interest because the variation observed there not only concerns a significant decrease of the electrical field between 1909/1910 and 1913 and 1923/1926, but also, the character of the diurnal variation of the electrical field has fundamentally changed. For the summer, the average value of the electrical field decreased from 50 to 37 V/m, for the equinoxes from 67 to 59 V/m, and for the winter from 104 to 86 V/m. The diurnal variation in the first period had a large morning maximum which for the later period is hardly visible. The explanation given is that between 1913 and 1923, home heating and cooking fuel changed from coal to electricity, thereby decreasing the aerosol density. For details, see Figure 177 on page 389 of Israël (1973), Dorno (1911), Lindholm und Bider (1927), and Israël (1948).

The North Atlantic case became well known when Gunn compared new measurements over the Atlantic Ocean with the results of the Carnegie cruises. He concluded that the aerosol content there had significantly increased from around 1920 to around 1960 (Gunn 1964). There has been some discussion about these findings. A suggestion was made that the conductivity measurements of the Carnegie ship had been influenced by a bias and would need correction.

From the host of other early examples, we select the following ones:

- Pierce discussed a possible influence from the fallout of nuclear explosions on atmospheric electrical elements (1957, 1958, 1959)
- Scrase (1934) reports on measurements done at Kew from 1843 to 1931
- Goldschmidt (1926) provides 3 years of measurements at Wahnsdorf--1923 to 1926. It is highly likely that many more series of durations of a few years will be found
- In his textbook on atmospheric electricity, H. Israël (1973) dedicated a special chapter (§64b, p. 393) to "secular changes" and discussed them also in §93, Atmospheric-Electric Synopsis, on pages 547 and 548, and occasionally at other places
- Possibile secular changes in thunderstorm frequency have been discussed by S.A. Changnon, Jr. (1977) for 1901 to 1960. Again, it is likely that similar evaluations could be done from other areas
- A rather early paper of the modern series considering the monitoring of pollution trends by atmospheric electricity is that of Manes (1977). More are mentioned in the main text of this document, pursuing it to the present.

These examples are but a selection. In general, the interest was directed to the local changes of conductivity or ion number density because of changes in aerosol or in radioactivity. Instead of looking into the conductivity and ion numbers, the electrical field also frequently served as a tool. As is well known, the electrical field is determined partly by the conductivity, and that is related to the ion count. Papers on the possibility of changes in earth-ionosphere potential difference, or on possible thunderstorm frequency trends, hardly exist beyond the few quoted here.

For a more systematic investigation, many old sources of data must be searched. We may find more papers directly dealing with such secular changes. A quick look into the material of one large library showed many sources. That search produced reports on series concerning only a few years, but they are spread throughout the world--from Antarctica to Greenland and Franz-Josefs-Land, from the Mt. Elbrus to other mountains and oceans, covering all continents.

Preliminary Discussion On Data Sources

I do not have enough information on the library at the Main Geophysical Observatory (MGO) in Leningrad to evaluate its potential for our purposes. However, it may be assumed that this library will indeed harbor many useful sources.

National Meteorological Library. Outside of the MGO, the most valuable source is probably the National Meteorological Library at Bracknell, U.K., in the Meteorological Office. After the observatory at Kew was closed, its treasures were transferred to Bracknell. Atmospheric electricity measurement began at Kew in 1843, but it must be assumed that continuous recordings, extended over years, had been done only in the 1960s, 1970s, and maybe 1980s. Interim shorter measuring periods are to be found--some carried out on the open plane with the equipment installed in an underground house. In addition, the register of the library stores the titles of thousands of papers and books on atmospheric electricity and, presumably, the books and articles themselves. I present a more detailed description below.

The library has a large card catalog that lists the authors of journal articles. Up to 1970, the subject catalog exists only in the form of books with a rather coarse subclassification, based on their own system at first and using the general decimal classification later. After 1970, the information is computerized.

In the domain of atmospheric electricity, we find two volumes of titles of papers and books and one with abstracts:

1. The first book covers roughly the first four decades of the 20th century, classified in the groups numbered 1605-1680. The titles of the papers and the source information are either typewritten (in some cases handwritten) or cut from printed tables of contents. Each chapter has approximately 30 to 50 pages with about 10 entries each. Subjects include
   - Dissipation of electricity, ionization
   - Potential variations caused by local atmospheric conditions
   - Potential periodic variations
   - Lightning
   - Ball lightning
   - Damage by lightning
   - Protection from lightning
   - Aurorae
   - Wireless in relation to meteorological conditions.
2. The second book contains selections of abstracts from articles written in the 1930s.
3. The third book is classified in 551.594.1 until 551.594.18, covering the four decades from the 1940s to the 1980s, each chapter has 40 to 50 pages with 10 or more entries each. Subjects include
   - Electrical phenomena in the atmosphere
   - Electricity in fine weather
   - Potential gradient
   - Ionization, charge
   - Ion mobility, conductivity, current
   - Radioactivity
   - Relation to other meteorological elements.

Since 1971, entries are computerized and can easily be printed; obviously, there is some duplication.

Maurice E. Crewe is the librarian, Bracknell is about 50 minutes train time from London Waterloo Station, and the library (next to Bracknell College) is a 15-minute walk from the station.

Address:
National Meteorological Library
London Road, Bracknell.
Berkshire RG12 2SZ
Telephone: +44 (0344) 856694
Telex: 849801

Meteorologisches Observatorium Potsdam. The Meteorologisches Observatorium Potsdam is another source. Atmospheric electricity measurements from various years, beginning shortly after the first years of the 1900s, are to be found there, either as digits or in the form of curves. For several decades, Potsdam was a leading center for atmospheric electricity research. The present director, Dr. Spänkuch, is aware of our desire to evaluate the historical data.

Other collections of books, papers, or even direct data probably exist (the library of the MGO was previously mentioned). The library of the Belgian Meteorological Service at Uccle may still store the results of, especially, Koenigsfeld's measurements. The Carnegie Institute in Washington, DC, probably still has the original protocols of measurements taken aboard the Carnegie and predecessors. The library of the Naval Research Laboratory in Washington, DC, is another source. Uppsala University may still have useful information, and so do others where atmospheric electricity work is continued (see Swider in Poland, Garmisch-Partenkirchen and Weissenau in Germany). The Deutscher Wetterdienst may still have somewhere some of the results of Israel's stations at Buchau, Aachen, and Nürburg. The U.S. Air Force should still have the data-filled reports of Israel's Alps Program 1954-57, and also from Holzer's American Program conducted under contract.

Colleagues who have done continuous measurements may be retired, but would be reliable sources. They may have older data themselves, they may know who has, and, above all, they may give valuable and important advice. Kasemir is certainly one of them; others may be found in France, Italy, Japan, and elsewhere. An inquiry at Socorro whether Crozier's data are still available, may open up an interesting source. In this sense, there exist many others (Albany, Duluth, Minneapolis, Ottawa). Listing such places unavoidably harms others not listed, and some broader sources should be mentioned:

- The comprehensive bibliography in Hans Israël "Atmospheric Electricity, Volumes I and II" (Jerusalem 1970, 1973), especially if evaluated with the text (to which each entry refers), will provide many sources.
- The proceedings of the atmospheric electricity conferences, listed at the end of the main text of this document, are promising material. One of them (Dolezalek and Reiter 1977) has a special index for localities. If one starts with this index of localities, go back to the articles to which they refer and find more there. However, even the over 300 localities listed, refer only to the ones that were mentioned during the Garmisch conference in 1974. Therefore, many stations are missing (e.g., three main English stations—Kew, Eskdalemuir, and Lerwick). Nobody mentioned them during the Garmisch conference.

Concluding Remarks

The first paragraph of this appendix shows the justification of this task which is outlined, albeit insufficiently, thereafter. The scope is difficult to assess; the task not only requires a lot of accumulation work but requests a certain degree of scientific judgement on the level of a doctor's or even Dr. habil's dissertation.

The task of understanding the most obvious variations of atmospheric electricity elements has been the topic of investigations over more than two centuries. However, even our older colleagues do not remember all the often important work done in this field before, say 1930, and for some of the younger ones that date is more likely to be about 1975. It is important to comprehend the results and arrive at a conclusion if enough of these problems have been solved.

The next step to look for other variations will automatically include the secular ones. There is no hope to understand them without the comprehensive results of the work showed in the previous paragraph. Take, for example, the result of measurements at Watheroo, Tucson, and Huancayo and other places that showed that atmospheric elements at various places of the world changed by about 20 percent related to the sunspot numbers (see Bauer 1926 and Wait 1937, 1942, and Wait and Torreson 1942. See Figure 152 on page 355, and Figure 294 on page 493 of Israël 1973). I am not certain whether we understand the reason, and it is questionable whether that fact would necessitate working with averages taken over 10 or 20 years to arrive at truly secular trends. The answer to this question depends on our understanding of the sun-spot relationship. I dare say that with enough understanding, we do not have to go to such long-time averages.

In general, it will not be easy to answer questions of this kind. Disappointment may often lead to canceling a plan whose possibilities have not yet been fully evaluated. Dedication to the task and optimism to try another way if one has failed, will be asked for, based on a solid knowledge of the science of atmospheric electricity.

We have here a set of problems well fitted to the present understanding of the concept of nonlinear dynamics. In this developing field, tools for the treatment of problems with similar degrees of complexity are being worked out. There is a chance that we will be able to use them.

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Appendix IV

Selection of Data for Collecting or Application (Fair-Weather Hour Syndrome)

With invited contribution by Edgar Knudsen and Sven Israelsson, Uppsala, Sweden[1]

Introduction

More than 40 years ago, Nikolai N. Paramonov of the Main Geophysical Observatory in St. Petersburg produced a remarkable analysis of atmospheric electricity data from land stations (Paramonov 1950, in Russian; see figures in Israël 1970 and 1973). He looked at atmospheric electricity data from about 60 stations around the world and filled in the gaps by theory. The diurnal variations of the electrical field at these land stations must have been similar to curves labeled "Potsdam" and "Kew" in figure 30 on page 82 of Israël (1970) (plotted in local time of the respective station). Paramanov's analysis automatically cancels the local meteorological variations, which occur at every place according to its local time. In this way, he produced the global curve (plotted in universal time) which is almost identical to the famous Carnegie Curve (see Israël 1973, Figure 174, page 384). One can conclude that the emerging global shares must have been incorporated, albeit mostly hidden, in all the source curves. For the present World Data Centre for Atmospheric Electricity (WDC/AE) in St. Petersburg, we must detect and identify these global shares in the present-day local results. It may be necessary to average, to this end, the daily results over several days. That will not hurt the purposes of WDC/AE, but it would be nice if the number of these days could be kept as small as possible.

Survey Of Task

The research aim has not always been clearly and expressly defined, but experiments to get solutions abound (begun long before Paramonov's days). See the text books by Israël (1970, 1973) and Chalmers (1967) and the Proceedings of the eight International Conferences on Atmospheric Electricity held from 1954 to 1988 (see pages 9 and 10).

However, all these, often rather intelligent, experiments only scratched the surface of the problem. The fundamental reason was a lack of focus. Rarely was a focus formulated[2] for atmospheric electricity research. Even more seldom was agreement reached between various researchers on a common focus. Consequently, sometimes the problems were not well defined before an experiment was planned. For the present focus on global change, our knowledge increased only slowly to a level in which an economic and purposeful set of experiments can be programmed. For example, we now believe that a combination of aerological and ground measurements, simultaneously located and timed after a plan, could make essential contributions. Despite a period in which many atmospheric electricity measurements were made in the free atmosphere by aircraft or radiosondes, such a deliberate combination was not tried, not implemented carefully enough, or not carried out over a sufficient time.

Atmospheric electricity measurements suffer from being very sensitive, so disturbances easily occur. Obviously, we are interested in finding methods that allow us to avoid or to filter out such disturbances; i.e., factors that disturb the very purpose of an investigation. This will be only partially useful. We must define successful cases so the unsuccessful cases can be discarded in any integrating procedures.

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[2]One isolated attempt for a focus was initiated by the World Meteorological Organization long ago: to learn how atmospheric electricity concepts and results could help other parts of meteorology (report by Dolezalek 1978). It remained without practical consequences.

There are obvious disturbances; i.e., when a bird settles on an antenna and again when it flies off, when the required high-ohmic insulation of the antenna from ground breaks down, when charged rain drops or snow flakes settle on an antenna, or when charged water drops fall from an antenna. Hours when one of these interferences are present must be discarded; often, the following hour must also be discarded. The more subtle and more interesting disturbances fall into categories that are essentially independent of each other: the

(a) Measurement itself may be faulty in a not-immediately recognized way
(b) Antennae are not placed on an open plane
(c) Measurement may be correct and the antenna placed on a free plane but the atmospheric electrical parameter that it measures may incorporate disturbing influences from meteorological or atmospheric-physical (other than electrical) processes occurring at the place of measurement. There are two types of such disturbances--resistive and generative.

Since all three are independent of each other[3], it is not admissible to select useable hourly averages from the form or values of the recorded curve as is often done, unless it can be shown that (a) did not play a role, or its quantity is known and can be subtracted, and that (b) did not apply. We will discuss these disturbances.

Test Of Correctness Of Measurement

In the cloud-free air volume and with field strengths well below the initiation of Townsend or other discharges, Ohm's Law must apply to the quantities of the electrical field, the current density, and the total conductivity of the air. In dealing with hourly averages, the displacement currents may be not considered but significant convection currents would not follow Ohm's Law. At the beginning, we consider only the conduction currents. If we try to verify this theoretical statement, we are surprised to which degree Ohm's Law is violated in the measuring results; in other words, how wrong these results must be. From this result, we cannot derive which of the three measurements is wrong. However, if Ohm's Law is nearly fulfilled, we can state that all three measurements are correct. We call the degree of fulfillment the closure of Ohm's Law and use the letter Ω for definition:

$\Omega = i/E(\gamma_+ + \gamma_-)$ = (direct current)/(indirect current)[4]

where i is the conduction current density (directly measured), E the intensity of the electrical field, and the γ's (gammas) are the positive polar and the negative polar electrical conductivity of the air (to get the total conductivity, we measure the polar ones and add them). Theoretically, if Ohm's Law applies, the product of field and total conductivity amounts to an indirect measurement of the current density. Such indirect measurements are often done. For aerological measurements of the current density, they are the standard procedure; but we do not intend to discuss aerological measurements here. The content (in detail) of this paragraph corresponds to Dolezalek (1960a); the information is in German. See also Israël (1973, pages 336 and 552), and some later treatments.

Measurements of Ω (Dolezalek 1960b) show that, depending on various factors, it may deviate considerably from the value 1, even in hourly averages from about $\frac{1}{4}$ to about 4 at certain stations. A heavy aerosol burden at the place of measurement will cause strong deviations from 1; i.e., such burden influences the correctness of the measurement of at least one of the three parameters. Sometimes Ω has a nearly regular diurnal variation. For satisfactory results, a station should always record all three parameters, calculate Ω, and exclude hourly averages when the closure is too large or too small. The limits should be determined after some experience, and conveyed to the WDC/AE when the data are submitted.

Violation Of The Free Plane Condition

The closure of Ohm's Law (Ω) also deviates strongly from the value 1 if the antennae are not mounted on a free or open plane. This condition has been discussed elsewhere in this document; Obviously, the free plane condition should be met whenever that is possible. Unfortunately, it is not always possible; e.g., in high mountain areas. In those cases, a reduction factor Re is applied, which is defined by:

Re = value on free plane/value at disturbed place.[5]

For details, see Israël (1973, page 335) and the literature given there. If Re were a purely electrostatic factor (disturbance of the electrical field by the obstacles), Re would be constant for a given place; unfortunately, it is not. Space charges drifting in the air and around obstacles influence Re. Often, it will have a nearly regular diurnal variation and random changes. Sometimes, it is even difficult to determine the values of Re; e.g., when there is no available free plane in the neighborhood. If it can be done, and Re can be measured for a prolonged time, at various times of the day, and under consideration of meteorological conditions, the application of Re to the measuring results would be more meaningful. If data are

[3] A mutual dependence between resistive ones and generative ones cannot be ruled out, but we hardly have more that speculative ideas about it.

[4] Refer to footnote 5.

[5] Since both Re and u are factors without dimension, care should be taken not to confuse numerator and denominator in these definitions. In both cases, the more direct value is in the numerator.

being sent to WDC/AE or used for publications, full information on Re should be included.

Resistive and Generative Disturbances: Basics

For this discussion, we consider the electrical field as the voltage drop caused by the air-earth current flowing vertically through a resistance, namely a vertical column of air. Seen this way, the current is the primary element at the measuring site. The current is being driven by the potential difference between ionosphere and ground. This is essentially a steady-state consideration.

If we go to the other extreme, we consider what will happen when suddenly the ionosphere-ground potential difference is applied to a formerly uncharged system. First, we have the same field strength in all heights, now acting as the primary element, causing currents that move the ions in such a way that space charges are formed. This changes the electrical field in all heights (increasing it below about 11 km, decreasing it above) until the steady state of the same current but different fields in all heights is reached. Restricting our discussion to hourly averages, in this way simulating the steadystate, we deal with the fact that the current is the same, independent of height.

This is true when the earth-ionosphere potential difference is the only cause of the current. If there are varying space charges in excess of the ones formed as indicated above, additional current circuits are formed. These "local circuits," cause additional (local) currents to flow between the "terminals" of these circuits.

We should consider what is meant by the term "varying space charges." If space charges of the same density move horizontally; i.e., along equipotential surfaces, no changes occur; they do not form a generator. If new, more or less dense space charges arrive by advection above a measuring site, they establish a generator. If new space charges are generated above the measuring site, again a generator is established.

What about vertical motion of space charges? If that vertical motion is along a column of constant conductivity, no new fields are generated or destroyed outside the range of the motion itself. That is not so if the conductivity increases with height. For our consideration, this may become important when the vertical conductivity gradient is significant. It is not significant if the height difference is small. Also, we often have the conditions met by Sagalyn and Faucher (1954)--conductivity within the exchange layer is nearly constant. These conditions may have to be considered, especially when dealing with the Austausch generator (Kasemir 1958). For it, our antenna may often be situated within the range of vertical space charge motion and therefore be in the local circuit of that generator.

Not considering any local circuits or local generators, the current is constant along height, depending only on the ionosphere-earth potential difference and the columnar resistance. If the local resistance (resistivity) is changed significantly in any height, the current will be influenced. However, the amount of change that can be called significant will differ greatly with height. We therefore must ask whether a variation of conductivity at the measuring place is large enough to be significant for the total amount of the columnar resistance. Only if this applies, will the current be considered as being influenced.

Resistive and Generative Disturbances: Conclusion

To determine the usefulness of recorded data of conduction current density, as a contribution to the determination of a global atmospheric electricity index (in analogy to the well established global geomagnetic index), quantitative information (or estimates) is needed about the existence and strength of local generators. Also, information is needed about any significant variations of the columnar resistance. This is in addition to information about the closure of Ohm's Law (Ω) in the measured data, and to information about the reduction factor, Re, to the free plane. These are the four factors that constitute the criteria for an hour with measurements or the hourly average. They are to replace the old notion of a fair-weather hour, reducing the criteria used for the determination of a fair-weather hour to bare accessories for the definition of truly atmospheric electrical criteria[6].

We have discussed the problems with Ω in the test of correctness of measurement and Re in violation of the free plane condition above and outlined the basics for electrical disturbances (for our purposes) in the atmosphere. Therefore, we must derive more detailed information on potential procedures to deal with resistive disturbances and generative disturbances.

Decision by Meteorological or Electrical Criteria

Electrical criteria are the desired one. They can be determined only by additional measurements or estimates. It should be investigated whether such additional measurements of electrical parameters are possible and promising. There are several possibilities:

Measuring the space charge density of the air close to the ground at the site of the antennae may give some clues. Further clues can probably be derived by measuring the number density of cluster ions and aerosol ions, or better, measuring their mobility spectra. Clues may also be

[6]This is a development parallel to the desirable replacement of the concept of fair-weather electricity by the domain of global-circuit electricity.

provided from determining the aerosol spectrum. To determine the convection current, a second air-earth current antenna may be used. The antenna would be exactly the same type and configuration as the first one, but positioned under a wide-meshed net to exclude the air-earth current. The net would be carried along at air temperature, if possible, and either grounded or kept at the varying atmospheric electric potential of its height.

Much more information can probably be derived from either of two possibilities to get data from aloft.

1. Float a small balloon on a thin, grounded wire in an altitude of 10 or 20 m, with a radioactive collector at the balloon and a small electrometer to measure the electrical potential at balloon height versus ground; data is transmitted by radio or by a second wire.
2. Erect on an isolating tether a larger balloon at 10 or 20 m above the station; the balloon carries instruments to measure space charge density there (maybe also conductivities and the electrical field, data transmission via radio or glass fiber).

Both balloon measurements will, however, work only if the height variations caused by air movement are small and slow enough to be accounted for. Whether a replacement of the tether by a pole is practical might be considered.

None of these additional measurements will give direct answers for the decision on columnar resistance or local generator. More discussion is needed to learn how these types of information can be used to derive useful knowledge for the determination of the global atmospheric electricity index. Many of these measurements can be interpreted only with the help of meteorological measurements, defining the atmospheric physical causes for variations of atmospheric electrical elements. Therefore, meteorological measurements will be needed too, as indicated below. However, it is possible that a relatively short application of all these additional parameters will be sufficient to get information for most of the future operating days of the station. These additional parameters should also be useful to establish the local air electricity database.

If no additional electrical measurements (such as described in the preceding paragraph) are done, we must resort to meteorological measurements or estimates. That seems to be a return to the old method of determining a fair-weather hour. Indeed, it includes these methods, but now more attention must be paid to the question how these meteorological criteria influence the electrical parameters. That is difficult. This task should be performed by a scientist who is well trained in atmospheric electricity and is familiar with the station and its environment. To leave this task to the scientist at the distant WDC/AE is a poor substitute. These meteorological characteristics will also be considered if the additional electrical measurements are being made. The meteorological information will be needed to interpret the additional electrical data and to determine when the electrical measurements can be discontinued. A sufficient relationship from them to the meteorological situation could be derived for future use.

Routine methods to determine the meteorological situation as it pertains to atmospheric electrical measurements at the same place use the following conditions for a "fair-weather" situation:

- No precipitation
- No fog
- No swirling snow
- No swirling dust
- Windspeed below 3 Beaufort
- Cloudiness less than 3/10 and not concentrated in the zenith.

For many stations, other criteria must also to be used, for example:

- Existing town in a certain direction and distance
- Aerosol-emitting factory
- High-voltage power transmission line
- Large body of water with white caps or breakers at the shore
- Blowing snow from high mountain range
- Large nearby waterfall
- Heavy traffic on neighboring street.

All these and similar sources of disturbance may make it advisable to exclude hours when the wind blows from that source toward the station.

Taking these meteorological data alone and in a straight-forward manner (i.e., defining a fair-weather hour under consideration of the special conditions of the station in question) does not solve the problem of conductivity changes or local generators that may occur in the fairest of all weathers. As to fair-weather conductivity changes, we refer to Israël (1973, pages 370-379 and elsewhere); for the fair-weather local generators see; e.g., Kasemir (1956) and Wåhlin (1988). In both cases, the additional electrical measurements discussed above may be helpful to make a decision whether or not the columnar resistance is varying and/or a local generator is acting significantly.

So far, we have pointed to the complexity of the problems involved and to some speculative or still hypothetical approaches to solutions. Obviously, further discussion and careful planning is needed before progress is be made in the indicated directions. This continuation of age-old discussions is now under a better understanding with potentially more direction and urgency. In the last section of this appendix, three schemes of symbols for the nomenclature are proposed that should be applied to give the various types of hours with data specific names.

These schemes have also been discussed at the Sixth Conference in Manchester in 1980 (see pages 9 and 10) but are not included in the proceeding. Another discussion took place during the negotiations on the Global Atmospheric Electricity Measurements Program (GAEM) (see Reiter 1990).

Nomenclature for Data Hours

Hourly averages of atmospheric electrical parameters, for which the factors Ω and Re have already been applied, fall into several categories depending on the existence of variations of the columnar resistance and/or local[7] generators. To give names for such hours, three schemes have been considered. In the first scheme, three-letter acronyms are combined. In the second scheme, numbers and mathematical signs are combined which allows easy classification of groups. In the third scheme, single letters are used.

Tables 1, 2, and 3 represent all three schemes--resistive, generative, and a combination. No recommendation is made for any of these schemes; it is also likely that finally other names may be agreed upon. We present them here so in a discussion, a relatively easy definition of the various types of hours can be applied.

Suggestion for rough evaluation of hours falling into one of these 12 groups:

For investigations on the global circuit, the groups CN and BN are of primary interest. For studies of atmospheric exchange processes (e.g., eddy turbulence) and/or on atmospheric pollution by neutral aerosols or on radioactivity in the atmosphere, groups VN and BN may be of interest, but in a different way. Groups CQ, BQ, and VQ may also be of interest in some cases. To investigate precipitation electricity or cloud electricity, the groups CY, BY, VY, and UY are probably interesting because either the generator effects in these cases will outweigh columnar resistance effects, or the interplay between resistance and generator variations will require special attention. Group UQ remains as the least desirable situation.

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[7] We considered only local generators in the troposphere. This is based on the assumption that local generators in the stratosphere or mesosphere, if they exist, may often not influence the vertical current flowing through the whole columnar resistance and therefore not affect the measurement at ground. A different case is given when significant horizontal electric potential differences exist in the ionosphere that have influences extending downwards. It is assumed that these "regional generators" do exist at least in high latitudes (auroral oval). That poses a host of new problems for atmospheric electricity, including the need to explain earlier atmospheric electricity measurement in high latitudes. In this document, restricting ourselves to the purposes of global change monitoring, we may be allowed to not consider the conditions of the polar regions and concentrate on moderate and low latitudes.

Table 1. Resistive Scheme

- An hour that is the center one of 3 (or more) hours during which the columnar resistance did not seem to vary significantly, or is constant, is called a

  "ConColRes Hour"

  or an

  "Hour in State 1 + "

  or a

  "C-hour"

- An hour that did not fulfill this condition; i.e., the columnar resistance is varying, is called a

  "NonColRes Hour"

  or an

  "Hour in State 1-"

  or a

  "V-hour"

  (for brevity, we left out the "Con" which logically should be in)

- An hour for which these conditions are unknown, is a

  "UnColRes Hour"

  or an

  "Hour in State 1?"

  or a

  "U-hour".

- These definitions do not yet include information whether 2 ConColRes Hours, separated by 1 or more NonConColRes Hours, represent the same value of the columnar resistance. It may be best to postpone any attempt to tackle this remaining difficulty. In many cases, the equality will indeed exist. If that is the case, one could call such hours also

  "BasColRes Hour"

  or an

  "Hour in State 1 = "

  or a

  "B-hour"

Table 2. Generative Scheme

The same principles for nomenclature applied to the problem of the local generators:

- An hour that is in the center between 2 hours without local generators that does not have a local generator acting either is called

  "NonLoGen Hour"

  or an

  "Hour in State 2+"

  or an

  "N-hour"

- An hour which did not fulfill this condition is called a

  "CumLoGen Hour"

  or an

  "Hour in State 2-"

  or a

  "Y-hour"

  It seems to be illogical how we applied the + and - signs, and maybe we should have a debate on this; we selected this choice because it would make a combination of two states with a plus sign (1 + and 2 +) the desired hour for global circuit considerations.

- If the given condition of local generator activity was unknown or questionable, we call such an hour an

  "UnLoGen Hour"

  or an

  "Hour in State 2?"

  or a

  "Q-hour"

  An analog to the "BasColRes Hour" or an "Hour in State 1" = or "B- hour" does, however, not exist for LoGen or State 2.

Table 3. Combination Resistive and Generative Scheme

Taking the definitions together, we arrive at 12 definitions for each hour of recordings:

ConColRes / NoLoGen	or	1 + /2 +	or	CN
BasColRes / NoLoGen	or	1 = /2 +	or	BN
NonColRes / NoLoGen	or	1- /2 +	or	VN
UnColRes / NoLoGen	or	1? /2 +	or	UN
ConColRes / CumLoGen	or	1 + /2-	or	CY
BasColRes / CumLoGen	or	1 = /2-	or	BY
NonColRes / CumLoGen	or	1- /2-	or	VY
UnColRes / CumLoGen	or	1? /2-	or	UY
ConColRes / UnLoGen	or	1 + /2?	or	CQ
BasColRes / UnLoGen	or	1 = /2?	or	BQ
NonColRes / UnLoGen	or	1- /2?	or	VQ
UnColRes / UnLoGen	or	1? /2?	or	UQ.

Recommendations For Conditions When Recording Atmospheric Electrical Parameters Related to the Global Circuit

An invited contribution by Edgar Knudsen and Sven Israelsson

Introduction

Ground-based measurements of atmospheric electrical parameters related to the global electrical circuit will give rise to considerable problems caused by local generators. Space charge cells of different sizes and density, moving at different speeds and at different heights will give fluctuating values of a wide frequency spectrum. Under unfavorable conditions, the recorded values can be several times higher than the values represented by the global atmospheric circuit.

A commonly used expression for describing the recording conditions is "fair weather conditions," which is mainly based upon visual meteorological observations. Considering the many hidden or nonvisual sources of local generators, visual observations by themselves can be significantly misleading. The origins of nonvisual local space charge generators can differ very much from one location to another. Some general sources are

- Electrode effect
- Radioactivity (natural and man-made)
- Particles torn off the ground
- Ground inversion (positive temperature gradient in the lowest atmosphere).

Unfortunately, the hidden or nonvisual space-charge generators are most dominant in the lowest atmosphere, where most of the measuring instruments are placed. To make accurate measurements of the global atmospheric electrical parameters, it is necessary that local generators have little or no influence.

A desirable solution could be establishing a quantitative factor; i.e., a numerical value characterizing the actual measuring or recording condition. We describe two methods that will provide numerical values for the characterization of a recording series of data.

Method 1

Space charges will always exist. The ideal condition would be when both the vertical and horizontal distribution of the space charge are homogeneous. This will probably never happen. The question will then be when one can reach conditions as close as possible to this ideal condition.

Assuming that the space-charge cells are transported by air movements, the formulas from micrometeorology can be applied (heat exchange theory). Close coupling between heat transport and space-charge transport has been found (recent results; not yet published).

The concept of the Richardson's stability parameter R_i, which is commonly used in micrometeorology, expresses the turbulent properties of the atmospheric surface layer.

Equation 1

R_i is defined as:

$$R_i = g/T \ (\delta T/\delta z + \Gamma) \ <(\delta u/\delta z)e^{-2}>$$

where:

R_i = Richardson Number

T = mean temperature in K

g = gravity constant

Γ = dry-adiabatic lapse rate (K/100 m)

u = mean wind velocity.

$R_i = 0$ means neutral stability of the layer

$R_i < 0$ gives turbulent mixing of the air; the lower the negative, the more efficient mixing

$R_i > 0$ leads to a stable atmosphere with limited vertical exchange.

From earlier investigations of radioactivity profiles, a fairly constant vertical distribution in the lowest atmospheric layer has been found for

$$-0.05 < R_i < 0.05$$

viz. near neutral stability.

Equation 1 shows that measurements of temperature and windspeed at two levels are requested for determination of R_i. A simplified method is to consider the windspeed at 0-level to be zero. In this case, only measurement of windspeed at one level will be necessary. Increasing windspeed gives decreasing R_i numbers, but still an upper windspeed must be stated. This represents the limit where particles are torn off the ground, giving rise to negative space charges.

Some rough values may be:

- Dry ground - about 6 m/s
- Snow cover - about 4.5 m/s (dry snow).

These limits will indeed differ from one site to another; it is recommended to check them for the actual recording station.

How to Detect Nonvisual Sources of Errors

Considering the local generators or the hidden sources of errors, we see that they have several qualities in common.

- They are all generating local space-charge cells
- Fluctuations are caused partly by air movements and partly by variable space charge density in the local air cells
- The effect is most dominant in the lowest atmospheric layer where ground-based instruments are placed.

Although the Faraday cage method can be criticized as not being an absolute instrument for space charge density measurements, it is a powerful tool for detecting local space charge cells. Besides, it is a simple device well suited for continuous recordings. Together with visual meteorological observations, recordings over a period will give a good impression of the local generators at the actual recording sites. Local conditions may vary from one site to another, so it will be meaningless to give general recommendation for such investigations.

Recommendations

Except for the visual errors, listed below, even statements of the influence of the hidden sources of errors should be considered.

Visual sources of errors.

- Thunderstorm conditions
- All kinds of precipitation
- Clouds (thin cirrus layer not in zenith can be accepted)
- Fog
- Drifting sand, snow, and dust
- Spray from breaking waves
- Haze (reduced visibility)
- Smoke, including vehicle exhaust.

Nonvisual sources of errors.

- Continuously record space-charge density for enough time to get a general impression of local generators
- State the upper windspeed
- Record simultaneously with a Faraday cage to detect short-term variations that otherwise could be interpreted as global phenomena
- Calculate Richardson's number keeping within the following limits:

$$-0.05 < R_i < 0.05$$

and continuously calculate 10-min. mean values for R_i.

Method 2

H. Tammet (private communication) proposes another method that has the same intent to give a numerical value for the quality of a recorded series.

The identification of global variation, if at all, is possible only in extremely low local variability. Therefore, we are interested first and foremost in a statistical model of low local variability, rather than a general statistical model of local variations. There is insufficient literature coverage about low variability situations.

In the observations of the global atmospheric electrical circuit, the weather is important as far as it influences local variations. Thus, the level of local variations is the primary criterion. Meteorological data must be considered as indirect information that can be used to predict the level of local variations of atmospheric electricity.

Experience shows that recording the vertical current density is a special situation where the direct estimate of local variability is easier and more exact than meteorological data. In local variability of the vertical current, the local component usually significantly exceeds the global component. Therefore, the general variability can be used as an estimate of local variability.

The standard deviation of an observation series is suitable as the quantitative measure of variability. The statistical estimate of standard deviations depends on the definition of elements and the length of the series. The recommendations are

- Estimates of an observation series are direct values of current density, recorded every second with a 1-km long wire antenna
- Estimates of a standard deviation are computed for every 600-sec segment of series independently of other data.

Observations are considered to correspond to the fair-weather condition, if

$$s < s_0$$

where s_0 is the conditional critical level. The value(s) of the critical level(s) must be determined during the actual observations. It is possible to fix several critical levels to classify the data according to their quality. Experience enables us to suppose that the value of the critical level 0.1 - 1.0 pA/m^2 are likely to find application.

The above proposal defines the criterion of fair weather separately for every 10-min interval. It is convenient to characterize long observational series by percentages of 10-min subintervals that correspond to the described criterion.

Discussion

As mentioned above, both methods have the same purpose--to give a numerical value for the quality of a recording series. However, using one method does not exclude using the other. Both methods have advantages and disadvantages. Method 2 is the simplest since it does not include recordings in addition to the current recordings, but it is in its present form restricted to current measurements. Method 1 would be more extensive, but can be applied to all atmospheric electrical parameters. For testing the closure of Ohm's Law, this would be essential.

Appendix V

Suggestion for a Pioneer Station on Global Circuit Atmospheric Electricity Measurements Centered at World Data Centre/Atmospheric Electricity

Introduction

Doubts are often voiced in the atmospheric electricity community about the global validity of measurements. This is especially true for measurements made by stations at ground on continents as their values reflect local disturbances (e.g., Lane-Smith 1977, Markson 1988). On the other hand, these doubts have not been considered as being substantial when it was decided to establish the World Data Centre for Atmospheric Electricity (WDC/AE). Also, the existence of the Carnegie curve and Paramonov's analysis (1950) could hardly be explained if there were no global validity.

Most scientists of this domain would agree that in very high atmospheric layers, close under the atmospheric electric equalizing layer, the electric potential versus ground would vary in time but would be the same everywhere on earth. Probably, exceptions are the polar areas where and when the cross-polar horizontal ionospheric potential differences are strong enough to be comparable to the vertical difference to ground[1]. The question then arises--how far we may move downwards; i.e., toward ground before significant horizontal potential differences appear, and how this depends on averaging, either in time or over area or both.

This question is difficult to answer. The necessary experiments have not been made that would provide the precision and reliability of decision-quality data. Markson (1988) bases his opinion on existing data. These data are, in turn, based on a situation in which the measuring techniques for continental groundstations were not fully understood. That is still the case.

Obviously, we are facing a problem that is crucially important for the work of the WDC/AE. It must be experimentally demonstrated whether the concept of atmospheric electric synopsis (Dolezalek 1958) and that of the global representation of ground data (in expansion of the synopsis) are realistic or not. That will involve an ability to separate, in local measurements, the global share (i.e., what happens electrically in the atmosphere of the whole globe at the same time) from the local share (i.e., any significant action of local generators, and any significant action of meteorology on the local columnar resistance). In principle, both shares are present in the measured data of the air-earth conduction current density.

The main text of this document provides the rationale behind the proposal for a pioneer station. This appendix is not more than an indication of possibilities. Each of its proposals is subject to and in need of further discussion and detailed assessment. A similar station was under construction at the Waldorf Observatory of the Naval Research Laboratory several years ago. That arrangement, at the time being of large interest but not vital for the purposes of the work at the Waldorf Observatory, was never completed. It is, in our opinion, now vital for the work of the WDC/AC.

The Problem

The most important problem is presented by the measurement of the conduction current density. There are several reasons for this statement. Local variations of conductivity, caused by meteorological processes, strongly influence the electrical field at that exact locality. However, if these conductivity variations are so shallow and/or so weak that they do not have a significant influence on the columnar resistance, they should not be a disturbance for the conduction current density. On the other hand, there are specific problems related to the current measurements. Some of the well-known problems of the electrode effect as well as the austausch-generator (Kasemir 1955, Wåhlin 1988) play a role here. The controversy between the "measured" or "directly measured" and the "calculated" or "indirectly measured" current densities[2] is still with us (e.g., Israël 1973 pp. 477-484. For a quantitative assessment, see Dolezalek 1960a. Also, see Israël 1973 pp. 334-337). This controversy involves the separation of the conduction from the displacement and the convective currents.

[1] This needs careful investigation which may result in a time-dependent limit of the undisturbed area of the low and moderate latitudes, accessible for global change monitoring in the way described in this appendix.

[2] A rather casual habit in discussions on atmospheric electricity is to use the work "current" when, in truth, "current density" is meant. This is permissible (and we do it here, too) as long as "real" currents are not considered, as is most often the case. A distinction is to be made when we consider something like the *Electric Standard Atmosphere* (Dolezalek 1988/89)

While the problem of the filtering out of the displacement current is solved, at least in principle, the separation of conduction and convection currents still poses important questions. There have been highly critical papers (e.g., Darayatna and Hutchinson 1977), and general treatments; (e.g., Morozov and Selezneva [1988]). According to Ruhnke (1991), the problem of the atmospheric electricity agitation (Israël 1973 pages 394, 408-416, 479, 591) likewise needs closer investigation. The necessary experiments should show to what degree these problems can be solved by better experimental data and how these solutions will change our potential to use atmospheric electricity for global change monitoring or other useful purposes.

Traditionally, measurements made directly at the ground have been considered to be the most representative ones. In some advance cases, measurements involve a Wilson plate antenna flush with the ground for the conduction current density, a field mill flash with the ground for the field intensity measurement, and Gerdien capacitors close to the ground for the polar conductivities. Such an arrangement is still the rule today, and historic data up to today have almost exclusively been obtained with it or with similar arrangements, considering, among other potential disturbances, the possibility of vertically moving space charges crossing the measurement height.

However, a proposal exists (Ruhnke, personal contribution April 1991) for a basic change. This new setup has been experimentally proven by H.W. Kasemir and L.H. Ruhnke, albeit only shortly and not in comparison with the traditional arrangement. In this new setup, the conduction current is measured by a horizontal wire about 10-m high (i.e., above the usual electrode-effect region). Then, the electrical field is measured with a passive wire antenna (Crozier 1963, Dolezalek 1963). The conductivities are measured (at the same height) by a capacitor-type arrangement consisting of a thin sensing wire in the axis of a cylindrical array of other wires for the driving voltages. Obviously, this new arrangement needs long-time testing in parallel with the traditional arrangements.

The still unsolved problems of the traditional arrangement must be attacked. Then, the traditional arrangement can be evaluated for verification of old data acquired with it at different stations. In addition, a meaningful comparison can be made with the new setup or any other arrangement.

Essential problems for establishing a pioneer station for the performance of the experiments needed are discussed in Section 55 of Israël (1971), supported by information contained in sections 32, 79, and 93. Since then, new information has been produced on individual parts of the problems discussed there (especially on the electrode effect), but the following basic situation is still valid.

The Solution

At a location in the midst of a large open horizontal plane where the soil and cover conditions are the same (say, a savannah or a desert), the results of measurements of the air-earth current density would be the same everywhere. Therefore, these results could be considered as being representative for a large area. The air-earth conduction current density depends only on the ionosphere-earth potential difference and the columnar resistance, which is expected to be the same everywhere above that plane. The electrode-effect space charges are moved by the wind. As a result, these motions (on average) occur horizontally; i.e., along equipotential surfaces. Therefore, they do not influence the electrical field (if this is measured with a sufficiently long time constant to smooth out the effects of small turbulences).

The situation would not change significantly if we put a few scattered houses on that plane, as long as the environment of the antenna itself is not affected by them. However, if one antenna were close to a house and another antenna at a large distance, both could not be expected to get the same results. Experience also shows that the ratio of the value at the open situation over the value of the data from the antenna near the house (i.e., the "reduction factor") is not a constant. Often, it has a diurnal variation and oscillations that look random. That shows that we are not dealing with a straightforward electrostatic problem. Obviously, varying space charge densities or movements are significant. We still regard the value at the open situation as representative. Thus, the value from the antenna near the house is *not* representative.

Which distances are required? The old Benndorf condition, albeit based on electrostatic calculations, is still valid in these conditions. It has been confirmed for "houses" or disturbances of any kind, even mountains. The condition states that the distance between the antenna and any field-distorting disturbance should be five times the height of that disturbance. If the disturbance is thin; e.g., a telephone pole, three times its height is permissible. If the disturbance is a hole in the ground or the antenna sits in an artificial plane above the ground, the rule of five times the height again applies. In the case of a plane with the antennae surrounded by a forest, but the distance between the rim of the antennae and the rim of the surrounding forest is at least five times the height of the trees, we still measure representative values. The current density thus measured would be the same as the current density over the forest around it (neglecting the shortcut of the columnar resistance by the height of the trees and neglecting the possibility of other influences from the forest on the meteorological conditions on the plane).

Considering the importance that these measurements and experiments have to the WDC/AE's work, would the location of the WDC/AE and the prevailing other natural conditions be suitable for establishing such a pioneer station? Fortunately, the WDC/AE is located in the Main Geophysical Observatory (MGO) in St. Petersburg, where one of the largest groups of atmospheric electricity scientists is assembled. Additional advantages are

- Close by, the MGO has a dependence in Voeikovo which is large enough and sufficiently well situated for a testing station for atmospheric electricity measuring techniques
- For a long time, the MGO has carried a significant tradition of atmospheric electricity measuring techniques. Remember, for example, the works of Imyanitov there. In fact, atmospheric electric experiments have been carried out in or near present St. Petersburg since 1753, albeit with tragic consequences. The researcher was struck by the lightning he tried to investigate.
- MGO scientists have participated in the many atmospheric electric investigations carried out in the former U.S.S.R., including the national conferences (e.g., at Naltchik 1990).

Two atmospheric electricity stations in roughly the same area have offered cooperation in these efforts of MGO, both being located in good geographic conditions and operated by scientists with expertise and genuine interest in these problems: Tahkuse in Estonia, 310 km southwest of St. Petersburg; and Uppsala in Sweden, 730 km west of St. Petersburg.

Perhaps an extensive investigation should start with the Wilson Plate measuring technique (horizontal plate flush with the ground as antenna). The most urgent problem is to investigate the electrode effect and the mechanical transport of charges to the antenna (the so-called convection current). This can be done by recording over enough time, air-earth current measurements with a variety of antennae, freely exposed or in connection with a screen. The following setup is recommended for discussion and eventual implementation.

Use six flat current antennae, flush with the ground, namely:

1. Solid metal plate[3]
2. Simple metal grid
3. Double metal grid spaced by about 10 cm, providing a field-free room under the upper grid
4. Double metal grid spaced by about 10 cm, with artificial α and/or ß radiation between (the radiation not penetrating the upper grid), creating an ion-filled room under the upper grid, the ions diffusing out
5. Flat, water-filled basin
6. Piece of natural soil with plant (grass) growth indigenous to the environment.

All antennae should be highly isolated with each feeding into an own electrometric amplifier. There should be connections to ground via a parallel circuit of high-ohm resistor and highly isolated capacitor, providing the correct time constant for the measurement of the conduction current only. The antennae should be in a sophisticated set-up with a varying resistor to follow the variations of conductivity of the air. During the operation, movable field meters could be brought close to these antennae to check the effect of the various kinds of air-earth current antennae.

Close to these six antennae, but far enough to avoid disturbing influence on them, there should be a seventh antenna, equal to 1 or 2 above, but being protected from the atmospheric electric field by an extended horizontal wide-meshed metal grid, erected 1 to 2 m above the antenna. The grid mesh size should be small enough to shield out the electrical field but large enough to let the meteorological exchange (that will carry ions) pass. Ideally, the temperature of that upper grid should be carried along at the temperature of the air at the same locality to keep the meteorological disturbance as small as possible.

Free-air insulators maintaining continuously a resistance of better than 10^{14} ohms have been developed and are available from industry. They have successfully operated in tropical and arctic climates and in between. For a sophisticated type, see Dolezalek (1956a, 1956b, 1961); the last publication describes an improved model and also the simple (but for its purpose, very effective) insulator by Bohnenblust. In addition, there should be two wire antennae at about 1.5 m above ground, one 10 m, the other one 30-50 m long, applying the Ruhnke/Kasemir method to measure the conduction current density Couple to ground these additional three antennae in the same way as for the six antennae discussed above. This enables measurement of the conduction current density only (plus the convection current if any) and not the displacement current density.

[3]This footnote applies to both 1 and 2 above. Between the plate or grid and the ground, there may be an electric field the intensity of which depends on the measured current density. This depends on the electronics of the measuring technique applied, and it may have an effect on the measurement.

Also, a much longer wire antenna to record the Maxwellian current density should be erected according to the set-up by Ruhnke, Tammet, and Arold (1963).

Of course, flush-with-the-ground measurement of (1) the electrical field and (2) the two polar conductivities and space charges will be needed. Other essential information would be the pertinent meteorological recordings, including the exact beginning of precipitation, radiation, cloudiness, visibility.

For a different type of investigation of the electrode effect, a variation of a set-up already existing at Voeikovo is suggested--place a field mill in the center of an elevated grid. Suggestions for modifications can be made. The setup should be away from any building, tree, or other obstruction at a distance not less than five times the height of that house. The grid should be large enough that the field mill is no closer to its rim than five times the height of the grid above the ground. The grid itself should be highly (ohmically) isolated from the poles holding it, so it can either be on ground potential or be carried along with the natural potential of its height.

The data should be recorded automatically. With the recording of the hourly average of each of the measured parameters and for each of the applied antennae, ratios of electrical field and sum of polar conductivities should be calculated to yield an indirect measurement of the air-earth current. Finally, the ratios to record the closure of Ohm's Law (the value of Ω) for each of the eight current antennae should all be calculated and recorded as hourly values. For the evaluation, the criteria of selection of data (see main text of this document) should be applied. Even that could probably be automated to a certain degree; i.e., subject to manual checking of the cases.

If occasional or regular aerological measurements (by radiosonde or aircraft) can be added, a station thus equipped would be the best possible set up to derive methods to separate global and local shares in the recordings. Thereby the best methods would be determined to monitor the global circuit.

Another important problem is given by the question of accuracy of the conductivity measurements. It might be helpful to find out which accuracy we can expect from the data on the conductivity measurements that are in the WDC/AE collection. Certainly, it is important to determine the accuracy for future measurements, the results of which will be used by the WDC/AE. In a very recent paper, Anderson and Bailey (1991) present a thorough investigation of this problem. On that basis, the WDC/AE may investigate whether special new measurements are to be made. Also, investigation could be made into which way a reliable accuracy report can be included in future data to be submitted to the WDC/AE.

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NEWS, NOTES, AND ABSTRACTS

Polar Lows Research

by J.P. Dugan and P.F. Twitchell. Dr. Dugan is an oceanographer currently serving as a Liaison Scientist for Physical Oceanography in Europe and the Middle East for the Office of Naval Research European Office. Previously he formed and directed the Field Measurements Department for Arete Associates. Earlier, he was at the Naval Research Laboratory, Washington, D.C. Dr. Twitchell is retired from the Office of Naval Research (ONR). He held positions at ONR Boston, the U.S. Naval Academy, Naval Air Systems Command, and ONR Headquarters. He is affiliated with the International Global Energy and Water Cycle Experiment Project Office in Washington D.C.

Introduction

Accurate weather predictions are important for safe operations of Navy systems throughout the world. The weather affects ships, aircraft, and personnel, and is critical to the performance of modern sensors and weapons. Nowhere is the impact of weather more important than at high latitudes where there can be sudden and extreme changes. There are many instances of unforecast winds that have risen without warning to hurricane force in less than 6 hours causing marine disasters. The principle difficulty to shipping has been icing of the superstructure and consequent loss of stability caused by blowing and freezing spray.

There are many reasons why the polar regions are special in regard to their meteorology. Consequently, polar weather research clearly deserves special attention if predictions are to be improved even marginally. Unfortunately, the situation is such that the current U.S. Navy Forecasters Handbook for the Arctic states: "Polar lows are difficult phenomena to forecast and seldom are forecast at all by numerical methods." This is a very surprising statement in this day of heavy reliance on computer-generated forecasts.

This article explores the whys and wherefores of polar lows and offers a review of recent research progress. Further intensive research is necessary if we are to improve the present situation. A plan has been put forward for a focused workshop to be conducted in June 1992.

Background on Polar Lows

As mentioned above, polar lows have been a subject of serious attention by all who have sailed the polar regions. Certainly early whalers and sealers returned from polar regions with tales of quick-striking and destructive storms. The Norwegian fishing industry, in particular, has a long history of concern with these weather systems as the small boats are easily overturned by the resulting heavy accumulations of rime. Many experiences have been documented. General interest reviews of the phenomenon have been provided by S. Businger in the American Scientist and by P. Twitchell a few years earlier in the Naval Research Reviews (Businger 1991, Twitchell 1987 and 1989).

These polar lows are mesoscale vortices in meteorological parlance and they are some of the most intense atmospheric systems found in the polar regions. They frequently have gale-, if not hurricane-, force winds and heavy falls of snow in parts of the North Atlantic, Gulf of Alaska, and other high-latitude oceanic areas. With a horizontal length scale of 500 km or less and a life cycle of 24 hours or less, they frequently remain undetected via the conventional meteorological reporting network and are therefore a major challenge to forecasters in the polar regions. In the presatellite era, almost nothing specific was known about this phenomenon. With the advent of polar orbiting satellites, the frequency and climatology of the systems can be investigated.

Despite the advantages that modern imagery provides in detecting the polar lows, more objective data are required on the structure and the environment where they occur. We can then fully understand their formation and permit their representation in numerical models of the atmosphere. The new generation of active and passive microwave instruments such as the scatterometer on the ERS-1 satellite and the Special Sensor Microwave Imager on the U.S. Defense Meteorological Satellite Program satellites offer exciting new opportunities to study the structure and dynamics of these systems.

More Detail on Polar Lows

The definition of a generic polar low has evolved significantly over the years. It typically refers to a small-scale (300 km or so across) cyclone whose main cloud mass is largely of convective origin that forms north of the polar front. Polar lows have been called arctic hurricanes, arctic lows, polar vortices, and *comma clouds*, the latter because of a characteristic signature sometimes seen in remotely sensed images.

Quickly developing, high-latitude weather systems draw their energy from the large potential that is available in the strong temperature gradients that occur near the edge of the polar ice cap. In regions where the flow of very cold air can be carried out over the much warmer ocean, this temperature difference can be enormous and supports massive heat flux at the surface and resulting large vertical convection in the atmospheric boundary layer.

There seems to be a difference between the Arctic and the Antarctic lows of this type. This is perhaps because the southern ocean has circumhemispheric winds that are largely unaffected by topography. Even though the Antarctic Peninsula has a long excursion to the northward, the water on either side is largely covered with a combination of glacial and sea ice, and air temperature differences are significantly reduced. The Arctic, on the other hand, has major meridional variations of topography and sea ice which provide locations where it is not unusual for cold air to be advected out over the warmer water. The two principal locations where this can occur are the Bering and the Norwegian/Barents Seas. In each case, there is a large land mass and/or ice cover to the westward. In the winter night, the near-surface air is cooled by radiation. Also, the prevailing westerlies carry this cold air mass eastward over the ice toward the open sea. The large gradient near the ice edge causes flow along the edge on average, but this flow is subject to shallow baroclinic instabilities that might act as a trigger for the storms. The process evidently is complicated since many small disturbances never gather much energy as they travel along the front, while others enter an explosive intensification stage. It is not known what causes a deep low to develop in some cases but not in others. Apparently similar situations and the solution of this puzzle will rest in our understanding of the physical processes and in the accuracy with which the dominant processes can be modeled. Since the spatial scale of the lows is so small, they are easily missed on computer models. They can develop, travel quickly, and in the confined northern seas, make a rapid landfall whereupon they quickly decay.

Scientific and Operational Progress

Although rudimentary knowledge about these storms has been available for a very long time, it was not until cloud images were obtained by the first orbiting weather satellites that the large number and variety of these storms were discovered. The imagery has provided very useful temporal data on the evolution of these systems. In addition, it provides a template on which to lay the very sparse *in situ* data that can be collected from ships, aircraft, or the occasional upper air sounding. The early researcher did not have the advantage that meteorologists have in midlatitude storms over land where the existing dense grid of meteorological reporting stations provides a synoptic picture of the weather systems. Thus, most of the research in this area has been carried out as case studies of certain storms with heavy reliance on satellite imagery through the 1970s and 1980s.

In the 1970s, most meteorologists defined polar lows as either small baroclinic waves or vortices akin to tropical storms. The confusion on how to define these storms continued through the earlier symposiums and workshop of the 1980s. A first symposium, under the auspices of a Norwegian Polar Lows Project, was held at the University of Copenhagen in August 1984. At this meeting there were discussions concerning where *comma cloud* circulations that form in polar air streams fit within polar low definitions. The technical papers presented at that meeting were published in a special 1985 issue of *Tellus* (Vol. 37A, No. 5). The U.S. Naval Air Systems Command increased funds for Arctic lows research in 1984 and sponsored a workshop in 1985 on the topic. The report (Kellogg and Twitchell 1986) on that workshop opened with the following quote:

> "The history of meteorology is replete with instances of some phenomenon in the atmosphere that defies an adequate description. We know that something exists, sometimes with disastrous consequences to people and their possessions, but its origins and evolution, and characteristics are only vaguely understood. Furthermore, it may even be hard for meteorologists to decide on what to call it."

Understanding of the physical processes that govern the genesis, maintenance, and decay of polar lows has advanced rapidly in the mid 1980s by investigators and operational meteorologists from both North America and Europe. The Norwegian Polar Lows Project, a joint effort between government, universities, and oil companies, was highly successful. Not surprisingly, as it was an initial effort, it stimulated many scientific questions and operational applications requiring further pursuit. The results of that 3-year Norwegian research program and development of operational numerical forecast models were presented at the International Conference on Polar Lows held near Oslo, Norway, in May 1986. Many of the technical presentations were published in another special issue of *Tellus* (Vol. 39A, No. 4) in 1987.

In 1985, U.S. Navy research activities were accelerated, while funding for National Oceanographic Atmospheric Administration (NOAA) and the Norwegian programs were ending. The interest and financial support by groups in the United Kingdom (U.K.), France, Federal Republic of Germany, and the Netherlands continued. The fruits of nearly a decade of research and advances in operational models were reported at a 1988 international workshop in Madison, Wisconsin. The majority of the technical papers presented were later published in a bound volume edited by Twitchell et al. (1989). Funding became fragmented in 1988. Although there were no follow-on U.S. Navy research funds, programs in operational applications continued. This was evident at the XV General Assembly of the European Geophysical Society held in Copenhagen on 23-27 April 1990. Papers from a special session on polar lows will appear in a third special issue of *Tellus*.

In addition, in early 1992, the *International Journal of Remote Sensing* will dedicate an issue to papers on remote sensing in polar regions. Because of the importance of polar lows, this issue will include many applications to polar lows research.

The advances in both the science and forecast models for polar lows, such as an operational model now in use by the Norwegians, in large part because of the refereed open literature publications and timely technical meetings of the polar lows community. The tradition of meetings and publications is continuing. At the International Union of Geology and Geophysics XX General Assembly in Vienna in 1991, the European Geophysical Society (EGS) Polar Lows Working Group hosted a meeting. Ten scientists attended and written reports submitted by others were discussed. A report on the presentations and discussions has appeared in *Polar Low News*, an occasionally published newsletter now in its third number which is edited by John Turner at the British Antarctic Survey in Cambridge, U.K. Advances in operational implementation were reported in Vienna by representatives of the University of Copenhagen, the Norwegian Meteorological Institute, Laboratoire de Meteorologie Dynamique, the British Antarctic Survey, the Alfred-Wegener-Institut, the University of Indiana, and the University of Bonn.

Several milestones are available as meeting reports by Kellogg and Twitchell (1986) and Rasmussen and Lystad (1987). Dr. Twitchell has played a prominent role in recent years because of his position as an ONR program manager especially interested in and supporting some fraction of the work in the subject.

The Future

Accurate predictions of these low-pressure systems remain beyond present capabilities in numerical weather prediction since they are so small, evolve so quickly, and occur in regions having only very sparse observations. The present situation of capable and experienced forecasters who depend largely on satellite observations must be improved to minimize errors (including those of missed events), inaccurate estimates of strength, and false alarms. A small group of researchers interested in the field is distributed throughout many countries. The group operates as a working group under the auspices of the EGS, has a mailing list of about 40 people, and publishes the newsletter noted above. To facilitate rapid progress, it is timely for this group to come together again in a workshop to discuss the many new observational tools being developed that will be available to researchers.

Plan for a Workshop

A workshop is being planned, potentially with the financial support of the Office of Naval Research European Office. The meeting is expected to be held on 23-26 June in Hvanneyri, Iceland, some 120 km north of Reykjavik. This workshop will be organized under the auspices of the European Geophysical Society Polar Lows Working Group comprised of.

- Professor E. Rasmussen - University of Copenhagen (Chairman Plan Lows Working Group [PLWG]) Dr. Rasmussen recently returned to Copenhagen from a sabbatical leave in the Meteorology Department at the Naval Postgraduate School in Monterey
- Mr. J. Turner - British Antarctic Survey (Secretary PLWG)
- Dr. P. Twitchell - International Global Energy and Water Cycle Experiment Project Office
- Mr. T. Jonsson - Icelandic Meteorological Service (local organizer).

The workshop is designed to bring together experts in the instrumentation, observations, and modeling fields. The purpose will be to advance our understanding of polar lows through the application of these new forms of satellite data. The first day will be devoted to presentations on new developments in remote sensing instrumentation. The second day will begin with presentations by all participants on their recent work. Then, the meeting will split into technical groups to work on case studies. Preliminary ideas for focus of the groups are satellite remote sounding using the TIROS operational vertical sounder, passive microwave for estimating precipitation, and scatterometer for estimating surface winds. The final day is expected to be devoted to final presentations, discussion of future plans, and writing assignments for publishing meeting results.

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French Scientists Awarded Prix Scientifique Philip Morris 1991

by Robert D. Ryan, a mathematician currently serving as a Liaison Scientist for Mathematics and Computer Science in Europe and the Middle East for the Office of Naval Research European Office. Mr. Ryan is on leave from the Office of Naval Research Arlington, Virginia, where he is Director of the Special Programs Office.

Patrick Flandrin received one of the six prizes awarded by the Association pour le Prix Scientifique Philip Morris (Association) in 1991. The award, one of two given in mathematics, was based on Flandrin's work over the last 10 years in signal processing and specifically for his recent work on representations of nonstationary signals. This latter work includes integrating the wavelet transform into a general framework of time-frequency and time-scale analysis. Dr. Flandrin is a member of Centre National de la Recherche Scientifique (CNRS) and heads the signal processing group in laboratory of physics at the École Normale Supérieure of Lyon.

The other mathematics award went to Jean-Michel Morel of the University of Paris-Dauphine for his work on image analysis and restoration. Dr. Morel founded and heads a group devoted to the mathematical analysis of image processing. Although the group's activity goes far beyond the application of wavelets to vision, multiresolution analysis and the wavelet transform are fully incorporated in their research.

Groupe Philip Morris established the Prix Scientifique Philip Morris in France in 1989. At the same time, they established the Premio Philip Morris per la Ricerca Scientifica e Tecnologica in Italy. Both prizes were inspired by the Forschungspreis created by Philip Morris in Germany in 1983.

A goal of the Association pour le Prix Scientific Philip Morris is to encourage French research towards technologies having practical applications to everyday life. The prize is intended to help support researchers advance their work and to bring public attention to their work. More generally, the Association promotes public interest in science. To this end, they have a contract with Agence Jules Verne, a French advertizing firm, to help publicize scientific research. In addition to providing recognition by the scientific community and the public, the prize includes a monetary award.

Each year a committee consisting of distinguished members of the French scientific community and working on behalf of the Association, selects three scientific themes and a jury. The themes for 1991 were mathematics, life sciences, and the science of man. The themes for the previous 2 years were astrophysics, information science, physical anthropology, biotechnology, earth sciences, and archeology. The committee aims to select themes over diverse areas of research--exact sciences, human sciences, technology, ecology--with an emphasis on areas where France has been an innovator and leader. The jury is selected to match the year's themes and thus provide expert judgement of the candidates work.

Although modern communication techniques are based on mathematics, the public often considers mathematics as being a completely theoretical discipline. The jury, in selecting Drs. Flandrin and Morel, wished to recognize pioneering research in mathematics having applications to technologies closely related to everyday life. In addition to being an honor to the recipients, this year's prize officially recognizes a growing body of applied research centered on wavelet techniques.

ESPRIT Basic Research Actions and Working Groups in Vision, Speech, Robotics, and Neural Networks

by Robert D. Ryan.

Introduction

Early in 1991, I put together an article entitled *European Strategic Programme for Research and Development in Information Technologies (ESPRIT) Basic Research Action and Working Groups in Computer Science* (*ESNIB* 91-01:15-28). Since the response to that article was enthusiastic, including a request for similar information on other areas, I have abstracted the ESPRIT literature for this article as well as another one on Natural Language, Artificial Intelligence, and Human-Computer Interaction. As indicated in the first article, the motivation is my observation that colleagues in the U.S. are, in general, not yet familiar with the full scope of the ESPRIT research programs and literature. The purpose of these articles is to make essential information about these programs quickly available to readers of *European Science Notes Information Bulletin* who have not acquired the original ESPRIT literature. For information on all of the ESPRIT programs, contact

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A new feature of ESPRIT, introduced since I wrote the first article on Basic Research Actions, is the concept of "networks of excellence." Initially, three such networks are being supported in speech and natural language, distributed computing systems architectures, and computational logic. I have included a description the speech and natural language program. Support for these networks is not intended to cover research or training costs. Instead, it is largely used to establish an administrative infrastructure and to organize meetings and workshops that permit members to coordinate the strategic planning of their research, exchanges of researchers and fellowships, and links to industry. Each network has its own internal structure dictated by the network's goals. Interestingly, membership in all three networks is open to any team of researchers in Europe who work in the area and wish to coordinate research and training activities.

Vision

Vision Systems for a Natural Human Environment (INSIGHT) Action Number 3001

Abstract: The perspectives of neuroscience, psychophysics, brain theory, mathematics, and computer vision research are used to study vision processing and develop new ideas on the functioning of vision systems able to operate in a human environment, rather than a simple "building-block" world.

The INSIGHT Action aims at a greater understanding of the following topics:

- Primitives for representing three-dimensional (3-D) surfaces underlying complex, local spatio-temporal, and higher-order spatial operations
- Computational procedures using these local operations that can be extracted from image sequences
- Flexible and dynamic combination of the various three-dimensional primitives to yield 3-D representations and to segment images
- Generation of 3-D surface models, and use of prediction to integrate these into object models, allowing the prediction of motor action effects and assistance in object and scene identification.

Research activities are grouped into four themes:

1. Higher-order local operations, studied anatomically and physiologically in the primate brain and psychophysically in human vision. Optic flow processing is receiving special attention, with the recovery of optic flow and its use in computer vision investigated under different assumptions.
2. Combination of multiple-depth cues, studied mainly from a psychophysical and computational point of view. The main topics are fusion of depth using cues from texture and stereo, and of structure using cues from motion.
3. Cue combination for image segmentation, studied from a neurophysiological and theoretical point of view. This research is centered on texture segmentation and segmentation by motion.
4. Surface and object representation, studied mainly from the computer vision point of view.

Results: A new and versatile setup for visual stimulation at 100 Hz is being employed in physiological experiments using state-of-the-art computer image techniques, and a new stereometer for the study of ground plans. Other achievements are new functions for cortical areas, a better understanding of the role of cyclotorsion in stereopsis, different techniques for recovery of optic flow, and new mathematical and computational theories about the extraction of shape from texture and shading.

An international symposium on INSIGHT's themes and findings took place in December 1991.

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Vision as Process (VAP)
Action Number 3038

Abstract: The integration of basic techniques for the construction of a continuously operating vision system capable of interpreting a dynamically changing environment is studied, concentrating on the control of perception via the goal-directed focus of attention. The approach uses spatial and temporal context, multiple resolutions, and controlled motion of the sensor system. The system definition phase has been concluded.

The VAP Action aims to demonstrate that the paradigm of "vision as process" is basic to the functioning of a high-level vision system. Such a hypothesis can only be demonstrated within the context of a complete vision system in which the potential benefits of continuous control of perception and of associated temporal context are evident. The goal of VAP is to adapt and refine existing vision techniques and to integrate them as a first step towards a general-purpose vision system.

Techniques to interpret a dynamically changing, quasi-structured environment are being developed. These techniques will use a goal-directed, focus-of-attention method involving controlled sensor motion. Processing will be directed by goals that change in response to the demands of the perceptual task, as well as in reaction to events in the scene. This approach is directed towards limiting the computational complexity of the perception process by restricting the size of the internal models employed. These models must be continuously updated to describe the environment in terms of a number of qualitatively different phenomena, such as image phenomena themselves, 3-D scene geometry, and symbolic interpretation of objects and events.

The necessary techniques will be developed in the context of an integrated vision system, which will serve as a means of testing the fundamental hypothesis.

The research issues to be addressed include:

- Role of contexts and goals in the control of perception
- Use of multiple resolution representation of two- and three-dimensional shapes (2- and 3-D)
- Description at multiple levels of abstraction.

Results: After the first year of the Action, the system definition phase has been concluded and reports produced outlining:

- Specification and pilot implementation of a skeleton system into which the individual functional modules of the system can be inserted and served with communication channels
- Prespecification of the basic modules comprising the system, which perform the following tasks: image description, extraction of a 3-D description, establishing and maintaining a 3-D model of the scene, scene interpretation, and control of perception.

So far, the work as well as the documents produced reflect an emphasis on the fundamental issues of the construction of controllable modules for dynamic computer vision.

The VAP Action is a member of the Vision Working Group (3352) and is actively involved in the organization of workshops and conferences. In April 1990, a workshop on Active Vision was held in connection with the First European Conference on Computer Vision. In September 1990, a Vision Workshop Week took place in Crete, where some of the latest work carried out in this Action was presented.

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Working Group on Vision
Working Group Number 3352

Abstract: The objective of this working group, a collection of 36 institutions organized into 6 consortia, is to forge a solid scientific community in vision in Europe by organizing meetings, workshops, and a scientific conference.

The objective of this working group on vision is to forge a solid scientific community concerned with the problems of machine and natural vision. This community is intended to serve as a spawning ground for future European projects. The mechanisms by which the group will accomplish its objective include the organization of meetings, workshops, conferences, and scientific exchanges, as well as the publication of books.

The group organizes scientific workshops on computer vision in topic areas proposed by its member consortia. These workshops provide a forum for the presentation of research in progress, and an opportunity for the scientific community to discuss current problems and results. The group is also involved in the continuing organization of the "European Conference on Computer Vision." The group actively encourages the participation of representatives from other ESPRIT projects at its scientific workshops.

The First European Conference on Computer Vision was held in Antibes in April 1990. Workshops organized so far have included:

- Control of Perception in Active Vision, Antibes - April 1990
- Real-Time Architectures for Computer Vision, Antibes - April 1990
- Learning in Vision, Antibes - April 1990
- Advanced Matching in Vision and Artificial Intelligence, München - June 1990
- From Pixels to Features II, Bonas - August 1990
- ESPRIT Vision Workshop Week, Iraklion - September 1990.

Approximately every 3 months, a newsletter is mailed all working group members.

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Speech

High-Resolution Speech Recognition: Auditory Connectionist Technologies for Speech (ACTS) Action Number 3207

Abstract: The computer modeling of auditory processing and connectionist systems for speech recognition is addressed. Based on research into peripheral auditory processing and cognitive research on speech perception and memory, the primary goal is to develop a recognition system that benefits from the preprocessing embodied in current models of the human auditory system.

The key research questions explored are:

- How can auditory processing performed in the cochlea be simulated?
- How can the transient information concerning the onsets and offsets of parts of speech be extracted from an early stage of the auditory processing chain?
- How can existing connectionist recognizers be developed to perform vowel recognition using the cochlea simulation as a front-end?
- How can training techniques for connectionist recognizers be improved?
- How do humans perform on a phoneme recognition task in the absence of lexical and contextual constraints?

The goal is to construct a recognition system involving (1) a high-resolution, front-end processor based on current models of the human auditory system, and (2) a word-recognition system based on abstract phonological representations and a phonological buffer store.

The three parallel research streams aim to

1. Develop a detailed but efficient functional model of human hearing in five stages: (1) spectral analysis, (2) neural transduction, (3) phase alignment, (4) pitch extraction, and (5) timbre stabilization. Feature extraction mechanisms used in the model will be developed in line with psychological research.
2. Compare connectionist recognizer performance using auditory preprocessing with conventional spectrographic preprocessing.
3. Develop new recognizer architectures and training algorithms in line with psycholinguistic research.

Work is also directed towards developing user documentation for the cochlea simulation software, establishing base-line performance for phoneme recognition using both traditional and auditory frontends, feature extraction software, and an efficient parallel implementation of a connectionist recognizer. Phonological memory research, experimentation concerning human vowel recognition, and human psycho-acoustical research are continuing parts of the project.

At the present time, developed software and published research on the action include:

- Efficient computer simulation of cochlea processing; documentation of the software for users in speech recognition and hearing research; published papers describing experiments on octave perception
- Efficient implementation of a connectionist recognizer producing performance comparable to the best Hidden Markov Modeling (HMM) recognizer; comparisons of the auditory model front-end with Fast Fourier Transform (FFT) filterbank; improved training and pattern-recognition algorithms
- Review of human vowel and consonant recognition research; experimental research on the structure of human phonological memory.

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Speech Processing and Recognition Using Integrated Neurocomputing Techniques (SPRINT)
Action Number 3228

Abstract: Various unsolved problems in speech recognition are tackled by exploring the particularities of neural networks (e.g., nonlinearity, self-organization, parallelism) to upgrade the performance of automatic speech-recognition systems. The connectionist paradigms are exploited to investigate some of the problems in relationship with speech variabilities: adaptation to new speakers and/or new environments, noise immunity, classification of speech parameters using a set of phonetic symbols, and recognition of isolated words (lexical access).

The aim of the SPRINT Action is to examine whether connectionist techniques can be used to improve the current performance of automatic speech recognition systems, with particular respect to speaker independence and noise insensitivity.

Answers are sought to the following questions:

- How can the recognizer be provided with robust features adapted to new speakers or environments?
- How can acoustic parameters be mapped onto phonetic symbols using different neural network paradigms?
- How can the competitive learning approach be applied to high-level speech processing to understand the lexicon structures?
- How can isolated words be recognized, considering the problems related to time-varying word patterns and noise immunity?

The speech representation levels considered are signal, parameter, phonetic, and lexical. The main areas of investigation are:

- Transition from the signal to the parameter level and transitions within the parameter level: research will provide the recognition system with a set of parameters leading to the best performance. Transformations of classical speech representations are investigated, based on multilayer perceptrons, topological maps, and the learning vector quantification method.
- Transition from the parameter to the phonetics level: various feed-forward neural network topologies have been assessed, and some found to integrate previous knowledge.
- Transition from the phonetic to the (sub)lexical level: the competitive learning approach is used to determine the structure of the lexicon and the structure between morpheme units and the phonemes.
- Transition from the parameter to the lexical level: the ability of various network paradigms to learn to generalize has been examined to deal with intra and interspeaker variability and background noise. The problem of recognizing time-varying speech patterns has been approached by transforming the speech signal to fit the fixed size network input layer. Architectures and hybrid systems that integrate neural networks with well-established approaches are used.

The available deliverables report on the following research activities:

- Theoretical studies that have been conducted to establish various neural network capabilities to generate any spectral transformation and their classification capabilities to discriminate between several classes, given a network architecture.
- Evaluation of speaker adaptation procedures based on learning spectral transformation with multilayer perceptrons. Well-established methods were compared.
- Use of neural networks to carry out the transformations of speech parameters necessary for recognition which is robust with respect to speech signals that are contaminated by noise. Preliminary experiments have been carried out.
- Examination of network techniques for spectrum classification and robust recognition of isolated words. Focus is on the evaluation of various structures of multilayer perceptrons and neural networks with different topologies.
- Use of added noise in training to improve generalization.

Work is now proceeding on developing a hybrid system, combining the technique of hidden Markov modeling with multilayer perception approaches.

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Articulatory-Acoustic Correlations in Coarticulatory Processes: a Cross-Language Investigation (ACCOR) Action Number 3279

Abstract: Modeling the underlying physiological and linguistic constraints is undertaken on the dynamics of articulation during speech production. A cross-language study of coarticulation identifies the major language-independent universal regularities of the phenomenon and how they interact with language-specific factors. Investigations of coarticulatory regularities are integrated with new and improved ways of exploiting these regularities in deriving articulatory representations from the acoustic analysis of speech.

Recent theoretical and experimental work on speech production strongly indicates the need for a comprehensive cross-language program of basic research to expand knowledge of the language-specific and -independent regularities involved.

For many applications in speech technology, the availability of an articulatory representation of speech utterances would mean substantial progress. For example, in the automatic recognition of continuous speech, one of the major barriers to robust speaker-independent systems has been the great variability in the relationship between the acoustic level of representation and the phonological structure of a given utterance.

However, the variability can become a productive source of information if the underlying physiological and linguistic constraints of the dynamics of articulation can be modeled. This is the goal of the ACCOR Action. The main source of systematic variability at the segmental level is undoubtedly coarticulation, the main focus of the work.

A cross-language approach is adopted in the ACCOR Action as a means of identifying the major language-independent universal regularities of the phenomenon (aspects such as mass, inertia, and elasticity of the speech organs; the mechanical linkages between them; and the neuromuscular complexities of the cranial nervous system), and how they interact with language-specific factors such as the phonological rules of the languages concerned.

Work began by examining the activities of the major physiological systems underlying speech production: the respiratory system (producing a flow of air), the laryngeal system (modifying the airflow by the valving mechanism of the vocal folds), and the complex supraglottal structures in the mouth and nose (such as the tongue, lips, jaw, and soft palate, which shape the vocal tract into different resonating cavities).

In addition, by examining the details of a given articulatory process for many different languages, ACCOR aims to determine how such processes differ according to different phonological systems. Thus, it can be in a position to investigate interactions between the two sources of variation. A common methodology, standardized investigation tools, and measurement procedures at specified locations in the speech signal have been adopted.

Deliverables and papers cover the following areas:

- Hardware and software development for digital recording of articulatory and acoustic data; a personal computer-based prototype of a multichannel speech workstation
- Research into the instrumental investigation of articulatory activity
- Review of connected speech processes in English, French, German, and Italian
- A core lexicon for English, French, Germ n, Italian, Spanish, and Swedish has been established consisting of consonant-vowel-consonant nonsense words, real words matching the phonetic structure of the nonsense words as closely as possible, sentences illustrating the main connected speech processes in different languages. A complete set of recordings is available for five speakers of each language
- Based on a nonlinear and independent annotation of the articulatory and acoustic events, a common methodology has been adopted for segmenting and labeling the data
- Interpretation of articulatory and acoustic data in terms of a production model is in progress.

A textbook on instrumental investigation of coarticulation will be published. Partners of the action will report its progress at the main international conferences (ASA, ICPhs, ICA). A symposium on "Speech Processes in the Light of Action Theory and Event Perception" was organized in Stockholm in August 1991.

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Robotics

Multisensory Control of Movement (MUCOM) Action Number: 3149

Abstract: Greater understanding is sought of how the brain builds an internal representation of space and movement to allow navigation, orientation, and action. This objective involves studying the questions of fusion of sensors, sensorimotor coordination, movement perception, posture control, and limb movement in biological systems.

The MUCOM Action aims to answer the following questions:

- Considering the multimodal perception of space and movement in natural systems, on what does the integration of sensory signals depend?
- What is the common frame of reference into which all sensory inputs are translated?
- How does the brain incorporate the geometric and dynamic properties of motor systems to elaborate movement command strategies?

- Considering the flexibility of the human and animal motor system, what strategies are used to control the execution of movement?
- How does information on simple motor effectors (such as the eye) compare with information about complex ones (like the head); what general principles underlay these mechanisms?

Research is focused on three areas:

1. Navigation - Looking at multisensory interaction in the generation of stabilizing eye and head movements, the multisensory detection of head movement, the generation of motor output, and problem-solving strategies. The methods used are behavioral and electrophysiological experiments on movement stabilization, and electrophysiological studies on curvation estimation in navigation trajectories. Theoretical models will also be constructed.
2. Orientation - Concerned with multisensory integration, sensorimotor integration, and calibration in the control of orienting movements. Investigations will be made into internal target representation and coding of eye position, premotor mechanisms (activity patterns and neuronal connectivity), and sensorimotor transformations. Anatomical and electrophysiological studies of the relevant systems will be performed.
3. Action - Centered on sensorimotor coordination in the control of the human upper limb. This part of the research will address representations of limb configurations, algorithms for limb coordination, and control mechanisms. These aspects will be investigated by recording the position of several limb joints via optoelectrical methods and by studies of task execution concerning visuo-manual coordination in humans.

Results: Novel methods have been developed in measuring 3-D eye movements using magnetic fields, histological techniques for marking neurons, manipulation of visual flow fields.

Insights have been gained in

- Neural mechanisms of visual motion perception
- Spatio-temporal transformations in neuronal pathways of the superior colliculus
- Bimanual coordination
- Eye-hand coordination.

Several simulation models of brain operations have been implemented on a computer and are being tested with biological data.

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Self-Organization and Analogical Modeling Using Subsymbolic Computing Action Number 3234

Abstract: Methods of subsymbolic computing are explored, with applications that include robotics and vision. The subsymbolic paradigms come from neural network learning algorithms and analogical representations mapped directly from the problem domain. The emphasis is on constructive problem solving, that is, the building up of solutions from scratch.

The action aims to obtain a better understanding of subsymbolic artificial intelligence and sensorimotor tasks. The key objectives are to:

- Explore an analogical representation in the form of a visual buffer which is used both to store expectations about a visual scene and to act as the medium in which sensorimotor actions are planned and monitored
- Use connectionist mechanisms to learn and compute generalizations about scenes with moving or still objects, so that concepts can be used to describe the scene and hence give verbal instructions, or that expectations can be generated by recognizing that the scene is an instance of a general class.

The action employs several approaches:

- A robot arm connected to a workstation grabs and moves target objects under the control of an internally maintained map. Reaction-diffusion dynamics on the map define the relationships of the different objects and the arm and thus perform the subsymbolic computations necessary for performing the tasks.

- An internal map of a street scene is maintained and used to plan trajectories for traffic. The computational operations performed on the map include those of generalizing from examples the generic forms of spatio-temporal events to build up subsymbolic schemata for planning purposes.
- A 2-D network of coupled oscillators is used for path planning. The "waves" interact with openings in "walls" to enable the simulated robot to choose a path suitable for its size.
- A reinforcement connectionist learning algorithm is used for robotic path planning. Two stages are involved: building an internal model of the workspace and constructing plans from particular starting configurations.
- Neural algorithms are explored for the execution of appropriate analogous dynamics ("internal simulations").
- Self-organizing maps are explored with application to scene analysis. The maps are used to evolve basic feature detectors appropriate to the images, and also in the construction of higher-level descriptions.
- The theoretical foundations of the approach are being analyzed and clarified. The Université Libre de Bruxelles (ULB) group is working on the application of dynamics for computation and the Geneva group on the relationships between the dynamic subsymbolic paradigm and Piagetan thought in cognitive psychology.

A common setup basic to the project has been realized at the Vrije Universiteit Brussel (VUB). This involves camera-robot-workstation communication and provides example scenes and problem formats for the other groups. Several papers have started to appear from the various groups, some in journals, and some in conference proceedings. These describe the implemented systems relating to the approaches listed above.

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Fundamentals of Intelligent Reliable Robot Systems (FIRST)
Action Number: 3274

Abstract: The integration sensing, planning, and control in robots is studied to further the development of more reliable robotic systems. This involves examining the fundamentals of task planning, geometric reasoning, control, and the use of different sensory modes such as seeing, grasping, and touching.

The basic aim of the FIRST Action is to integrate components of sensing, planning, and control to increase the reliability and flexibility of robotic systems. The use of sensors is an essential component of a system that must plan and execute actions intelligently and reliably. Intelligent manipulation must be based on the relationship between nonlocal sensing such as vision and hand/eye coordination, and between local sensing and grasping. Control actions need to be related to task descriptions and the shape representations that support planning.

Research is proceeding on pair-wise interactions between sensing, planning, and control. This approach is a step beyond work restricted to one or two of these topics, and is expected to result in more reliable and intelligent systems.

Results are given in three areas:

1. Sensing and planning - Work has concentrated on developing reliable vision methods for gross planning and on studying the role of sensing force, tactile data, and proximity in the process of grasp planning. New vision methods have been developed that can reliably extract feature information and associate with model databases. A modeling system has been developed that generates 6-dimensional, contact-force information from geometric models of the environment. A study was conducted on the uncertainty introduced by errors of the manipulator or other parts and their effect on contact planning.
2. Sensing and control - Work has concentrated mainly on vision, both as a means of exploring the environment and as a way of monitoring it. Experiments have been conducted in the field of extracting object features via vision. The main results in this area are a new knowledge-based

architecture for manipulation, experimental results on pushing and grasping, and a new method for extracting feature descriptions from both pushing and visual information.

3. Planning and control - Work has concentrated on methods of transforming plans into action, motion planning under uncertainty, and learning control strategies. Progress has been made in gross-motion planning for two robot arms in a completely unknown environment, and also in fine-motion planning for grasping operations with large model uncertainties.

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Neural Networks

Action Numbers 3228 and 3234 can be looked upon as neural networks research. Because of context, they are naturally classified under speech and robotics, respectively. The action described below is more general in scope.

Innovative Architectures for Neurocomputing Machines and VLSI Neural Networks (NERVES) Action Number 3049

Abstract: The theoretical tools and technical means for designing algorithms, machines, and very large-scale integration (VLSI) circuits for neurocomputing are being developed. Research is proceeding into connectionist algorithms and architectures for data processing with learning and recognition capabilities, the design of high-speed parallel neurocomputing machines for distributed algorithms, and the design of application-specific integrated neurocircuits with analogue and/or digital features.

Neurocomputing algorithms are known to be very efficient for information processing, but they consume large amount of computational resources. The key research questions address the problems of how to design neurocomputers suited for simulations and application-specific integrated neurocircuits for real-time applications.

The work has been divided into 5 research packages:

1. Neural architectures and algorithms - Looking at the visual processing of text and silicon implementation constraints and implications
2. Language and software tools - Focusing on developing a high-level specification language
3. Neuro-coprocessors and architectures for neurocomputers - Examining systolic circuits, general-purpose neurocomputers, and neural network implementations on massively parallel computers
4. Application-specific integrated neurocircuits - Studying the design of associative memories and source separation circuits
5. Cells and technology - Addressing the design of pulse-stream synapses, building blocks for analogue implementation and design technology for analogue synapse memory.

Each task will result in state-of-the-art reports and demonstration products.

Deliverables and publications on the results of the following tasks are available:

- Visual processing of text - General architecture has been specific and the front-end processing of big rams through retinotopic learning maps has been assessed
- Silicon implementation constraints - Main problem of accuracy in the sum-of-products operation has been evaluated in various application programs, ranging from content-addressable memories to multi-layer perceptrons
- High-level specification language - Definition and specification of the language has been completed and the grammar will follow
- Architectures for neurocomputers - Both small and efficient neuro-accelerator boards and a more general-purpose neurocomputer, SMART, have been specified; prototypes have been available since early in 1991
- Application-specific integrated neurocircuits - Several chips have been realized for associative memories of source separation; analogue and digital techniques are available
- Cells and technology - Techniques library is available as building blocks for pulse stream synapses, cascadable synaptic matrices, and analogue synaptic memories.

The action organizes three meetings each year, which are open to a limited number of external participants.

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St Patrick's College - Dublin	Ireland
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Network of Excellence in Speech and Natural Language

This network will provide an infrastructure for coordinating research and postgraduate training activities on a European scale. The long-term goal is to contribute towards constructing an integrated model of the "cognitive chain" linking speech to reasoning via natural language. At a practical level, research towards this goal will involve building systems that can both automatically understand speech and enable speech to be synthesized from abstract representations of meaning.

Although it is unlikely that constructing large-scale integrated speech and natural language systems can be achieved within a decade, the network should greatly accelerate progress towards this target. The network will also help reconcile opposed methodological positions that are currently hindering fruitful interdisciplinary cooperation between the two research communities.

By building on structures and collaborative research projects already present at the national and European level, the network will use the personal and intellectual ties that are vital for such a large-scale cooperative venture. Moreover, it will encourage technology transfer by increasing the level of interaction between academia and industry, and will promote activities that produce a variety of industrially relevant results during its lifetime.

An initial network of managing and associate nodes has been identified, but it is intended that the network will acquire considerably more associate nodes once it has been established, and that the structure as a whole will evolve dynamically over the coming years.

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Comments

Please note that the abstracts in this article represent only the basic research being supported by ESPRIT in the four areas. For each area--vision, speech, robotics, and neural networks--there are other ESPRIT projects with a more applied or "marketplace" focus. Projects on computer vision are found under Information Processing Systems and Computer-Integrated Manufacturing. Research on various aspects of speech can be found under Information Processing Systems and Office and Business Systems, while robotics research is well represented under Computer-Integrated Manufacturing.

Neural networks research was originally and most prominently represented by PYGMALION (Project Number 2059) and Applications of Neural Networks for Industry in Europe (ANNIE) (Project Number 2092). PYGMALION ended in February 1991 and ANNIE ended in November 1991. GALATEA (Project Number 5293) builds upon the results from PYGMALION with the objective of constructing a general neural computing system for Europe. Thomson-CSF continues to coordinate, but the group of partners and associate contractors differs from the PYGMALION group.

Structural Acoustics at the Office National d'Etudes et de Recherches Aéronautiques

by G.L. Main, Program Manager, Structural Acoustics, Advanced Vehicles Division, Applied Research and Technology Directorate, Office of Naval Research, Arlington, Virginia.

Introduction

The Office National d'Etudes et de Rechershes Aéronautiques (ONERA) consists of about 2,000 people with about 1,000 at Chatillon, France (a suburb of Paris).

About 30 percent of the ONERA budget comes directly from the Ministry of Defense (MoD) with the remainder from contract research. Since overhead costs can easily account for 30 percent, the goal is to maintain close to 100 percent contract research support. The major sources of contract research are various French MoD agencies and the European Space Agency.

The ONERA's eight departments are:

1. Systems
2. Aerodynamics
3. Energetics
4. Materials
5. Physics
6. Structures
7. Large Testing Facilities
8. Computer Science.

Structures Department

Roger Ohayon is the head of one of the research groups at ONERA concerned with structural acoustics; C. Soize heads the other group. Ohayon's group has cross connections with the physics and the materials departments. Approximately 10 scientists are working in the group with about half having a Ph.D. and the other half working on a Ph.D. with local universities. The common arrangement seems to be that the research for the Ph.D. is carried out at ONERA under the joint supervision of a university faculty member and a group leader or senior scientist at ONERA. Ohayon is now a faculty member at the University of Paris. Thus, he can also be the student's advisor.

I asked Ohayon to explain how ONERA became involved in structural acoustics since ONERA is intended as an aerospace research organization while structural acoustics is normally more strongly associated with naval interests. The connection is via the Ariane program. The Ariane launcher is liquid fueled and thus consists of large fluid-filled structures subject to excitation by large dynamic forces during launch. While the problem of aeroelasticity (the interaction of the structure with the air) is a traditional aerospace problem, the problem of the interaction of the structure with the liquid fuel is much more akin to the structural acoustics problems of naval interest. As a result of the experience ONERA gained in looking at Ariane structural acoustics problems, they began to look at naval problems beginning in about 1980.

We discussed three projects within Ohayon's group:

1. Update finite element methods (FEM) with experimental data
2. Doubly asymptotic approximation methods for structural acoustics
3. Noise reduction coating design.

Update Finite Element Methods with Experimental Data

The general concept in updating of FEMs is that some experimental data may be available but not for every node of the FEM model. The ONERA work assumes that displacement measurements are made at a subset of the FEM nodes and that stiffness matrix contains the errors that must be updated. The ONERA approach to the problem uses static substructuring to split the model into submodels with independent resolutions, therefore affecting a considerable reduction in computational cost. A cost function is formed based on the errors in displacements at the experimentally known nodes. The ONERA method is described in detail in a recent paper using a two-dimensional truss (Berger et al., 1990). Henri Berger,

Roger Ohayon, and graduate student Francois Quentin are the collaborators in this work. As a result of interest in the area, a European working group has been formed to study various methodologies and develop benchmark problems (GARTEUR-AG). This group involves participants from France, the Federal Republic of Germany, the United Kingdom, and the Netherlands.

Doubly Asymptotic Approximations

Doubly asymptotic approximations (DAA) originated in the U.S. with the work of Tom Geers at Lockheed, Palo Alto, California, in the early 1980s. This method consists of creating a matched asymptotic solution to an acoustic or vibration problem based on high- and low-frequency asymptotic solutions. Bernard Nicolas-Vullierme, a researcher in Ohayon's group, spent a year at Lockheed in Palo Alto and subsequently brought an interest in DAA back to ONERA. Nicolas-Vullierme's DAA work emphasizes working directly from the integral equation representation for the Helmholtz equation rather than from the boundary element method (BEM) generated matrices. The origin of DAA was in the treatment of shock problems in which in the asymptotics of high and low frequency are critical to the solution. Using DAA for steady-state structural acoustics problems is relatively new and puts a premium on higher order asymptotic approximations since most of the energy is neither high nor low frequency. Nicolas-Vullierme's work with derivations of DAA formulations directly from the Helmholtz integral equation potentially allows access to higher order DAA approximations (Nicolas-Vullierme, B.).

Noise Reduction Coating Design

Ohayon's group is also involved in designing noise-reducing coatings for submerged structures. This work is being conducted by Daniel Osmont and Nicolas-Vullierme. Work in this area was begun in 1986 and is intended to design coatings that reduce radiated noise. The FEM modeling is the primary tool in this effort that seeks to optimize the design of coating based on layered structures and encapsulated microstructures. The microstructures give the potential of independently controlling density and compressibility within desired parameters while using the viscoelastic properties of the bulk material to achieve impedance matching and absorption in a limited thickness of coating (Nicolas-Vullierme and Osmont, 1990).

Additional Information

In addition to the structural acoustics work in Ohayon's group discussed above, there is also ongoing work in power flow analysis, wave propagation, nonlinear dynamics of structures, and buckling of composites. Besides Ohayon's group, C. Soize heads another group working in structural acoustics. Soize is well known for his development "fuzzy structural theory" (Soize, 1985). Unfortunately, I was unable to meet with Soize.

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Acoustics Research at the Institut Superieur d'Electronique du Nord

by G.L. Main.

Introduction

The Institut Superieur d'Electronique du Nord (ISEN) is located in Lille, France, near the Belgian border. Created in 1956, ISEN is an engineering school that serves the needs of northern France. I met with Drs. Jean Decarpigny and Bernard Hamonic. Decarpigny was head of the acoustics department but is now in charge of institute academic programs. I believe this position would be comparable to a vice president for academic programs in a U.S. university. In spite of his new position, Decarpigny maintains an active role in research in the acoustics department. Hamonic is now head of the acoustics department.

The ISEN is a specialized institute that admits only about 110 students annually into its engineering programs. In the first 2 years of the program, which is called classes preparatiores or the first cycle, the curriculum is composed mostly of mathematics and the basic sciences. At the end of the first cycle, an average of 90 students remain. At that point, about 20 more students are admitted with a DUT from French high schools that teach the first cycle for engineering and about 10 students from university first cycles. The second cycle consisting of 3 years culminates in the engineering diploma. The second cycle divides the students into programs in the five departments that constitute both ISEN's research and teaching specialties—solid-state physics, microelectronics, acoustics, control science, and computer science. The ISEN is also beginning a branch school in Toulon which is expected to have a signal processing department.

The ISEN is private school but has connections with the Catholic University of Lille that allows ISEN students to take courses there. In fact, the Catholic University has about 10,000 students and is joined with five small institutes (including ISEN) in a federation. In graduate education, ISEN is similar to U.S. universities in the relation of research to education.

Research

Research at ISEN is carried out with both external sponsorship of projects and direct support from Centre National de la Recherche Scientifique (CNRS). Decarpigny describes CNRS as the closest French equivalent to the National Science Foundation. In an arrangement novel to U.S. observers, some ISEN staff is directly employed by CNRS while they work at ISEN. In some cases, they are paid 100 percent by CNRS. In other cases, salary is divided between ISEN and CNRS.

Comprised of about 15 research staff, the acoustics department has both experimental and modeling projects. The department is perhaps best known for developing and maintaining the ATILA finite element (FE) code for transducer modeling. In 1978, ISEN began to develop ATILA. The ATILA is widely used in French naval laboratories concerned with acoustic transducers. Now it is also being used in some U.S. Navy laboratories and the Naval Postgraduate School. The ATILA uses FE to model the transducer itself and presently uses fluid FE to model water surrounding the transducer. A boundary element (BE) code is being developed to handle the fluid part as an option in future versions of ATILA. The FE model of the transducer itself includes capabilities for elastic, viscoelastic, and piezoelectric and magnetostrictive active materials. The active material and viscoelastic material capabilities are essential elements for transducer modeling but not commonly found in FE codes not specifically aimed at transducer modeling. An interesting note about the formulation of the coupling between the fluid FEs and the solid FEs is that a special element of zero thickness is used to connect displacement elements in the solid to pressure elements in the fluid. In addition to modeling transducers, ISEN builds and tests transducer designs. In particular, the ISEN design efforts (as opposed to modeling only) center on flextensional designs in which the displacement provided by the active material is amplified via the geometric configuration of the transducer. In low-frequency transduction, the active materials available generally have less displacement than desired, but more force available than necessary. Thus, designing transducers that transform force into displacement is important. Flextensional designs are the major means of accomplishing the force into displacement transformation and such designs require FE analysis to predict performance.

The ISEN has also done some transducer array modeling and composite material modeling for noise reduction coatings with ATILA. In array modeling, the mutual interactions of the transducers are important. Thus, a coupled FE model of each transducer with an FE model of the fluid in between them is necessary. For noise reduction coatings, ISEN researchers have looked at the modeling of two types of composite materials:

1. Alberich coating in which periodically spaced cavities are placed in a viscoelastic material
2. Piezoelectric damping in which piezoelectric elements are placed in the coating and coupled to passive electrical circuits.

In both cases, the modeling requirements appeal to the special capabilities of the ATILA code to handle viscoelastic materials and active materials—thus, the ISEN interest.

In the acoustics laboratory facilities, I noticed two major infrastructure items for doing experimental work: (1) a large water impedance tube and (2) an 8- x 6- x 6.5-m-deep water tank. The impedance tube is about 10-cm diameter x 2-in long and has a transducer at each end. Material samples are placed in the middle of the tube with one transducer acting as the source and the other providing active suppression of reflection from the terminating end of the tube. The reflection and transmission coefficients of the material sample can then be obtained. The water tank is usable for experiments down to kHz and has an array of automated instrumentation data acquisition and analysis.

Summary

The ISEN specializes in both research and academic programs around specific technology areas and achieves integration of research and teaching in these areas. Acoustics is the department rather than a program within a department. The acoustics department specializes in transducer modeling and design, and other closely related work such as noise reduction coatings. The acoustics department receives about 5 million French francs ($1 million) annually in contract research from various French naval agencies primarily as a result of its franchise in transducer work. The acoustics department is interested in collaborative research efforts and educational and research exchange programs. In the references below, a description of ISEN activities can be found in Lannoo. Work related to the ATILA code can be found in the others.

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Metravib—A French Company Involved in Acoustics

by G.L. Main.

Introduction

Metravib is a French company that is strong in acoustics and vibration-related (including shock) materials work and the related technologies. The company carries out its work in Ecueillé, near Lyon, France, and consists of a staff of approximately 115 people. Metravib was founded in 1968 with six people from the military shipbuilding industry in France and has grown to its present size over the past 22 years. I met with Dr. Bernard Garnier, Metravib's marketing manager for the defense sector and several the technical staff.

Contracts

Metravib's first contract was with the Naval Underwater Systems Center, Newport, Rhode Island, to supply equipment to measure dynamic stiffness and complex moduli. Metravib's customers now range from military to commercial. For the next 5 years, Metravib will install instrumentation on all new propellers and torpedoes for the French Navy. For the most part, this work involves developing thin conformal sensors for various physical quantities, particularly pressure and acceleration.

Metravib also supplies whole systems of sensors for French nuclear powerplants for pressure, temperature, and acceleration measurement. Other contracts involve the manufacture of high shock sensors made of polyvinylidene fluoride for Sandia National Laboratories, Albuquerque, New Mexico, and Michelin for numerical modeling and test methods.

Projects

Metravib has been involved in acoustic coatings and materials for the noise reduction in both self noise, which affects hull mounted sonar arrays, and radiated noise, which makes a vessel more easily detectable. There two sources of self noise:

1. Flow induced noise from turbulent flow over a hull
2. Noise generated by onboard equipment such as pumps.

Metravib redesigned a sonar dome on a ship-towed submersible with an active array inside the dome, while the original dome was a ribbed steel structure. The redesigned dome with a layered composite structure containing damping layers achieved 10-dB, self-noise reduction. (Restrictions prevented discussing the original self-noise level or frequency range.) Metravib also claims to have achieved similar self-noise reductions for torpedoes. Garnier said that attempts to reduce radiated noise may increase self noise. Most of the energy in self noise is nonradiating evanescent noise propagating around a hull or remaining strictly local. Whether the source of noise at a given frequency is turbulent flow or internal machinery, most of the energy on the hull from that source has wavenumbers too small to radiate. To radiate the noise must have a wavenumber larger than the acoustic wavenumber in the water that corresponds to the given frequency. The exceptions are that discontinuities on and curvature of the hull allow radiation at less than the acoustic wavenumber. Many schemes intended to reduce radiated noise are based on decreasing the energy content at radiating wavenumbers and may, in the process, increase the nonradiating noise which is the primary component of self noise.

Metravib and Thomson-Sintra are suppliers for flank arrays. These arrays consist of pressure and acceleration sensing elements embedded in a coating. The coating in which the sensing elements are embedded is backed in succession a hard reflector, a soft reflector, an acoustic screen, and the hull.

The hard reflector is one whose impedance is large compared with water; e.g., steel. The soft reflector is one whose impedance is small compared with water—typically, a polymer containing some air. The acoustic screen contains a "complex of mechanical elements and materials," according to Garnier. Metravib produces the low noise accelerometers, the soft reflector, and the acoustic screen. This work is for new submarines being built.

I saw a noise reduction (radiation reduction) coating that they have designed for the new French submarine design. The coating consists of a viscoelastic material with large elliptical cylinder cavities measuring approximately 5 inches on their major axis. Garnier stated that the lower limit of good performance is 500 Hz. Otherwise, details of the coating design were not given.

Another topic discussed was the use of granular materials for damping inside the structures of the next French submarine. Such materials have a sharp cutoff in frequency, are insensitive to temperature and nuclear radiation, but are sensitive to humidity. Metravib is involved in analyzing the structural response with such materials included in the structure.

For work in radiated noise, Metravib has developed a numerical tool called GAP for predicting radiation from elastic structures (hulls). C. Avellet, the primary researcher at Metravib, described the work to me. At present, GAP assumes a infinitely long hull (the far field is calculated from a Helmholtz integral that considers the finite length of the actual hull). The hull is divided into "elementary bays" that can be represented analytically through a transfer matrix. The water is represented by a finite difference scheme in both the radial and axial direction. The hull is assumed to have axial symmetry. However, forces or structures inside the hull need not be axisymmetric because the solution can be analytically broken down into circumferential harmonics. Metravib claims to achieve accurate radiation predictions with GAP

(see Garnier, B. et al.). Metravib is working on methods to terminate the shell and is also developing a scattering version of the GAP code. Garnier says they have also developed a turbulent boundary layer simulation for GAP. CERDAN, a French Navy laboratory, and other navy-related facilities in France use GAP.

Metravib work in "cleaning and smoothing" of experimental data was briefly discussed by J.M. Parot (1989). He also discussed numerical applications of "fuzzy set theory."

Summary

Metravib conducts a full range of work from analytical and numerical simulation to the production of sensors for industrial applications. I did not view the production end of Metravib's work. Also, I did not investigate Metravib's work on active vibration and sound control. Metravib is a significant component of French underwater acoustics efforts, and is interested in more international involvement.

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Bernoulli Society Meets in Israel

by Dr. Murad S. Taqqu, Professor of Mathematics at Boston University, Boston, Massachusetts. Dr. Taqqu is investigating stochastic processes and time series with long-range dependence and high variability.

Introduction

The Bernoulli Society (Society) is an international organization whose aim is to further contacts between mathematicians and scientists working in stochastic processes, probability, and mathematical statistics. Among its many activities, the Society sponsors an annual conference on stochastic processes and their applications. This year's conference took place in June 1991 in Nahariya, Israel. I will describe (nontechnically) some of the talks presented at the conference, give a feeling for the Bernoulli Society and the state of probability in Israel.

The 1992 conference will be held at York University, Canada, which is near Toronto. In 1993, it will be in Amsterdam, the Netherlands. For information about the 1992 meeting, write to:

Stochastic Processes Conference
Department of Mathematics and Statistics
York University, 4700 Keele Street
North York, Ontario M3J 1P3, Canada.

Probability in Israel

Most probabilists in Israel are in Haifa at the Technion, Israel's Institute of Technology and its oldest university. The Technion's probability group is scattered among three departments. Its members, however, maintain close contact and share a common weekly colloquium.

Moshe Zakai (stochastic analysis and filtering) is in electrical engineering. His 65th birthday was the occasion of a 3-day conference on stochastic calculus. The invited papers have been published (Mayer-Wolf et al., 1991).

Ofer Zeitouni (large deviations, filtering, and stochastic analysis) and Adam Schwartz (stochastic control and applied probability) also belong to electrical engineering. Ross Pinsky (diffusions and large deviations), Eddy Mayer-Wolf (filtering and stochastic analysis), Yehoram Gordon (Slepian inequalities and Banach space probability), and Boris Granovsky (interacting particle systems) are in the Department of Mathematics.

The third department where many probabilists work is industrial engineering and management. Robert Adler is in Gaussian processes and random fields, and Haya Kaspi is in Markov processes and regenerative systems. Other members of the department include Paul Feigin (inference for stochastic processes and applied statistics), Ishay Weissman (theory of extremes), Michael Rubinovitch (queuing theory and applied probability), and Avi Mandelbaum (queuing networks and applied probability).

At the University of Tel Aviv are Isaaco Meilijon (modeling), David Gilat (stochastic ordering and martingales), Jon Aronson and Meier Smorodinsky (ergodic theory), and Pavel Bleher (statistical mechanics). Bleher recently arrived from the former U.S.S.R. where he worked with Roland Dobrushin. Boris Tsirelson (mathematical physics and Banach spaces) is also an immigrant from the former U.S.S.R.

Bar Ilan Univerity in Ramat Gan near Tel Aviv has Ely Merzbach (stochastic calculus) and Kenneth Hochberg who was at Case Western University, Ohio (measure valued processes).

The Hebrew University in Jerusalem is the second oldest university in Israel and now has two campuses. The Department of Mathematics is on the Givat Ram campus and the Department of Statistics is on the Mount Scopus campus. Harry Furstenberg and Benjamin Weiss (ergodic theory) and Yuri Kifer (dynamical systems) are in the Department of Mathematics. Esther Samuel-Cohen and Moshe Pollack (sequential analysis), and Gideon Schwarz are in the Department of Statistics. While not exhaustive, this list indicates that probability is strongly represented in Israel.

The Conference

I will describe some of the talks presented at the conference focusing on the general flavor and avoid technicalities. I take full responsibility for the descriptions as they reflect my own understanding of the lectures. A complete list of abstracts (Abstracts, 1991) will be published in the journal *Stochastic Process and their Application.*

Diffusion on a Fractal. Diffusion processes in space are by now well understood. Martin Barlow, Imperial College, London, considered Brownian motion on the Sierpinski carpet. This carpet is a fractal on the unit square whose dimension equals log 8/log 3, approximately 1.89, hence slightly less than the dimension 2 of the unit square. The carpet is obtained by removing the middle squares from the original unit square and iterating the procedure. After defining a Brownian motion at each iteration, one obtains Brownian motion on the carpet by a passage to the limit. Whereas the unconstrained Brownian motion at time t has a variance (mean squared displacement) equal to t, Brownian motion of the Sierpinski carpet has a smaller variance because the carpet slows it down. Barlow obtained several properties of Brownian motion on the carpet; e.g., the strong Markov property, reversibility.

Conditioned Brownian Motion. Tom Salisbury, York University, described conditioned Brownian motion, a process obtained by forcing Brownian motion to stay in certain regions of three-dimensional space and to move in preferential directions. Although strictly speaking, the result is not Brownian motion anymore, it is still often a Markov process and of a special type, because it can be described analytically in terms of so-called harmonic and superharmonic functions.

These functions usually appear when solving certain differential equations with boundary conditions. Many complex analytic notions involving the differential equations acquire a nice physical interpretation in terms of conditional Brownian motion.

An Important Example is the Notion of Martin Boundary. Consider Brownian motion on the plane and condition it to reach a given point on a given horizontal segment. The point can be reached from above the segment or from below. These are two essentially different situations. They correspond analytically to having the physical boundary (the segment) split in two (the so-called Martin boundaries). Salisbury illustrated the phenomena and indicated how one can force Brownian motion to "accelerate" by conditioning it to move through narrow corridors. Some aspects of the presentation were related to Martin Barlow's talk on diffusion on a fractal.

How Brownian Motion Survives Among Random Traps. Alain-Sol Sznitman is well known for his work on the development of chaos in stochastic systems. He was educated in France, became professor at New York University, then in January 1991, moved to the Eidgenössische Technische Hochschule (ETH) in Zürich, Switzerland. Sznitman described his recent work on Brownian survival among random traps.

Consider a D-dimensional Space with Traps. These are balls of a given radius whose centers are randomly distributed through space (as a Poisson point process). A Brownian motion starting at the origin will get killed if it hits a trap. How likely is it to be still alive by time t? Sznitman shows that the probability of survival decreases to zero exponentially fast as t tends to infinity, with rate proportional to $t^{(d/d+2)}$. The rate does not depend on the radius of the balls. Sznitman obtains this result after a suitable rescaling, where space becomes a forest and the traps are trees. The process will survive for a long time only if it hits a clearing. Clearings are rare. They determine the probability of long-term survival.

Optimizing a Portfolio. Ioannis Karatzas of Columbia University, considered a control problem which can be best formulated as a portfolio optimization problem. For stock and bond investing, one wants to find the optimal portfolio that maximizes the mean utility of the wealth in a finite time horizon. The bond price evolves deterministically in time but the prices of the stocks change randomly. They are modeled as dependent exponential Brownian motions. The optimization problem mentioned above has an easy solution. If, however, the portfolio (that is, the mix of stocks and bonds) is constrained to stay in a closed convex set, a physically realistic situation, then the problem is more difficult. Karatzas solves it by embedding the constrained problem in a suitable family of unconstrained ones obtained by adding *ad hoc* complementary slack variables and using duality. It turns out that one of the many unconstrained problems is a solution to the constrained one.

Anticipative Stochastic Control. The classical theory of stochastic integration assumes that the integrand is nonanticipative. That is, it depends only on the noise observed up to the present. There have recently been several attempts to develop an anticipative theory of stochastic integration. However, there is very little work on stochastic control when anticipation is allowed. M.H.A. Davis, Imperial College, London, editor of *Stochastics*, described some ideas on the subject.

Assume only slight anticipation from the present. Perform a nonrandom optimization by optimizing on each sample path. Then view these paths as random and take expectation. To compensate for the anticipation, add a linear penalty to the cost function. Anticipation is slight so linearity is justified. Interpret the Lagrange multipliers that arise from the optimization as a measure of sensitivity to the anticipation.

Maxima of Random Fields. David Siegmund, Stanford University, California, is the President of the Institute for Mathematical Statistics, the U.S. professional society for probability and statistics. He presented methods to analyze maxima of random fields. A random field is a multidimensional stochastic process. Finding the maximum is of interest in many applications. It is also an important problem in statistics. For example, consider several probability distributions. Suppose that you want to test the hypothesis that they all have equal mean, versus the alternative, that their means take different specified values. The test involves sums and differences of random walks. Although each random walk involves a single index, the various sums and differences give rise to a process indexed by several parameters; i.e., a random field. One must evaluate the probability that the random field crosses a certain level. Different methods have been developed in the last 20 years, yet none are uniformly best. All the methods yield asymptotic results. Aldous' recent book (1989) describes a technique that is often difficult to implement in a rigorous fashion but is heuristically appealing.

Local Time of Markov Processes. Markov processes occur in many applications, but their local time (the amount of time they spend at a certain level) is not easy to analyze. Michael Marcus, City University, New York, makes use of the remarkable Dynkin's isomorphism theorem discovered by Eugene Dynkin about 10 years ago (1984). Eugene Dynkin, Cornell University, came to the U.S. from the former U.S.S.R. almost 15 years ago. He is the father of the modern theory of Markov processes and is one of the foremost probabilists of our generation. During my visit to the former U.S.S.R. in 1981, I was asked the following two questions: Does Dynkin like the U.S. and does he have students? While I expected the first question, the second was puzzling. It turns out that he was known as the "teacher" par excellence! Many of the prominent Soviet probabilists studied under his direction. His departure was a great loss to the former U.S.S.R.

Dynkin discovered the isomorphism theorem several years after his arrival in the U.S. The theorem provides a way to associate analytically certain Markov processes with Gaussian processes: the Laplace transform of the transition function of the Markov process becomes the covariance function of the Gaussian process. Gaussian processes have been extensively studied and are by now well understood. The isomorphism theorem allows one to use properties of the Gaussian process to obtain properties of the corresponding Markov process. Marcus uses this technique to study properties of the local time of Markov processes; e.g., modulus of continuity, oscillation.

High Variability and Maxima of Random Variables. Brownian motion is a Gaussian process. At each fixed time it has a Gaussian distribution. Hence, it is very unlikely that it takes values far away from its mean. High variability, on the other hand, arises when the corresponding stochastic process or random noise takes large values with high probability. Examples include rain data, relaxation times of solid-state materials, and the broadband noise generated by some submarines. Such noises can be modeled by stable distributions.

To compare expected maxima in the Gaussian case, one uses the Slepian inequality. The conditions involve covariances as these characterize the distribution. But in the stable case, both variances and covariances are infinite. Reporting on recent joint work with G. Samorodnitsky, Cornell University (Samorodnitsky and Taqqu, 1991), I described the corresponding conditions in the stable case. Our conditions involve stochastic monotonicity, a notion that has been extensively used in the context of reliability theory.

Acknowledgments

This article is based in part on discussions with Paul Embrechts, Professor at the ETH, Zürich, and Scientific Secretary of the Bernoulli Society, and Robert Adler, Professor at the Technion, Israel.

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Polymer Surfaces and Interfaces II, an International Symposium

by Kenneth J. Wynne. Dr. Wynne is Program Manager, Organic and Polymeric Materials, Chemistry Division, Office of Naval Research, Arlington, Virginia.

Introduction

Polymer Surfaces and Interfaces II, an International Symposium, was held in Durham, United Kingdom (U.K.), in July 1991. The meeting was a sequel to one organized in Durham in 1985. Meeting participants stayed in student housing at University College in Durham Castle. Although built in 1072, the accommodations are of more recent vintage.

Polymer surfaces and interfaces provide challenging scientific problems and have enormous practical importance in many technologies. The objective of this meeting was to assemble approximately 100 scientists from chemistry, physics, materials science, and technology to stimulate a fruitful exchange of ideas and information.

This meeting was organized by Professor W. James Feast, Professor of Chemistry at Durham. Professor Feast also codirects a new government-funded interdisciplinary research center for research on advanced polymeric materials. The symposium speakers were from the U.K. - 8, the U.S. - 5, Sweden - 2, and 1 each from Australia, Belgium, the Federal Republic of Germany (FRG), Holland, Ireland, and Japan.

The meeting content was highly interdisciplinary, covering contributions from biochemistry, chemistry, physics, materials science, and technology in the sense of instrumentation development. Presentation categories were theory, instrumentation, and chemical surface modification. The presentations on theory sought to model polymer surfaces and interfaces and to relate theory to experimental data. Instrumentation and instrumentation development constituted the bulk of the presentations and included improvements in well-established techniques and capabilities of new techniques. Efforts in synthesis were directed toward polymer surface modification by chemical and photochemical approaches.

Fundamentals and Theory

The thermodynamic basis for polymer interactions was presented by Professor C.J. van Oss, Department of Microbiology, SUNY Buffalo, New York. He pointed out the various forces between polymer molecules including:

- van der Waals
- Ionic
- Hydrogen bonding and Lewis acid base
- Hydrophobic interactions
- Hydration pressure
- Steric interactions; e.g., stabilization of polymers in water by nonionic surfactants
- Cross binding (polymer/particle)
- Specific interactions; e.g., enzyme/substrate.

The various interactions were considered in turn, and special attention was given to the contribution of acid-base interactions to surface tension.

Dr. M.E. Cates, Cavendish Laboratory, Cambridge, U.K., gave a presentation on theoretical aspects of polymers attached to surfaces. He focused on the statistical mechanical approach to the description of chain molecules and addressed several polymer types Particular attention was given to polymer brushes, which is a polymer chain backbone of one character with sidechain groups (bristles) of a second character.

Instrumentation

The presentation of Professor D.L. Allara, Department of Materials Science, Pennsylvania State, concerned infrared spectroscopy in the analysis of monolayers and multilayers. The systems that were investigated were molecules that form layered structures via the Langmuir-Blodgett technique. These are generally small molecules such as long chain fatty acids and related molecules. Infrared spectroscopy is especially useful in determining composition, order, and orientation in these thin films.

Continuing with the topic of vibrational spectroscopy, Professor Ronald J. Young, University of Manchester Institute of Science and Technology (UMIST), U.K., described polymer surface and interface characterization using Raman spectroscopy. In his approach, a light fiber brings the interrogating laser beam to the sample surface. In this way, a spot size of 2μm may be interrogated. Depth of penetration of the laser beam is material dependent. For a relatively nonabsorbing material such a Kevlar, penetration is 1μm. With a Kevlar fiber sample mounted in the grips of a load cell, it was observed that several vibrational modes decreased in frequency with increasing strain. Thus, one can study stress-strain behavior of an isolated fiber alone or in a matrix. Analyzing the stress response of the Raman spectrum allows the differentiation of well-bonded fibers from poorly bonded fibers.

In an elegant fashion, Professor Jean-Jacques Pireaux, University of Notre-Dame de la Paix, Interdisciplinary Laboratory for Electronic Spectroscopy, Namur, Belgium, obtains vibrational spectroscopic data utilizing high-resolution electron energy loss spectroscopy (HREELS). In this method, a high-energy electron beam impinges on the sample and the scattered electrons are analyzed to determine energy loss. Because a fraction of the electrons that interact with the sample experience energy loss through interaction with vibration modes, part of the energy loss spectrum reflects the vibrational spectrum of atoms near the surface.

This technique is very sensitive to surface composition as the depth of analysis is only about 20 Å. This was shown by an experiment wherein a monolayer of deuterated polyethylmethacrylate (DPMMA) (i PMMA) was overcoated with successive monolayers of normal PMMA. The C-D and C-H stretching modes are clearly separated and observed with up to two monolayers of PMMA over the initial monolayer of DPMMA. After three monolayers of PMMA are coated over DPMMA, the C-D stretch is no longer detected. Thus, interrogation depth is about 20-25 Å and the sensitivity to the chemical nature of the surface is a major advantage for this technique.

Because most polymers are insulating, the interaction of the electron beam with the polymer produces charging effects. Such effects can greatly alter baseline spectra. Thus, for this technique to be successful, the polymer sample must be rather thin (300 Å) and the film must be formed on a very smooth conducting substrate. Furthermore, surface sensitivity of different vibrational modes is not easily quantified.

Dr. G. Beamson, ICI Wilton Materials Research Center, Wiltshire, U.K., reviewed a technique known by two names:

1. Electron spectroscopy for chemical analysis (ESCA), as it is commonly called by chemists
2. X-ray photoelectron spectroscopy (XPS), as it is commonly called by physicists.

This is a high-vacuum technique related to HREELS in which x rays impinge on the sample and eject electrons from various energy levels in the sample. Chemical information is elicited in this technique, as the energy required to eject an electron from a given element (e.g., C-1s) depends on the chemical environment. Thus, for the classic case of poly(vinylidene fluoride) (PVDF), $(CF_2CH_2)_n$, separate C-1s binding energy peaks are seen separated by about 5 eV. At the usual take off angle of about 75°, ESCA interrogates about 50 Å in depth.

This paper emphasized advances in instrumentation that have led to better resolution of peaks because of differing chemical environments. With an x-ray monochrometer and optimized instrumentation, spectral resolution for polymeric solids approximates that observed in the gas phase. As with HREELS and other techniques where high-energy radiation interacts with an insulating polymeric solid, charging effects in ESCA can be severe, leading to spurious peak positions.

Dr. J. Lub, Philips Research, Eindhoven, Holland, presented a lecture on the application of static secondary ion mass spectrometry (SIMS) to polymer surface analysis. In this method, the sample is bombarded with ions such as H^+ or Ar^+. The fragment ions that are generated at the surface of the sample are mass analyzed. Dr. Lub emphasized the analysis of negative ion peaks. Negative ions are less plentiful, and with fewer peaks the spectra are much easier to analyze.

This technique is very sensitive to the presence of volatile species near the surface. Thus in the SIMS spectrum of a sample of poly(bis-phenol-A)carbonate, a prominent peak revealed the presence of the mold-release compound $[CH_3(CH_2)_3C(O)OCH_2]_4C$ in addition to peaks attributable to the polymer.

Dr. M. Stamm, Max Planck Institute for Polymers, Mainz, the FRG, described the characterization of polymer surfaces by reflectivity and interference techniques. Dr. Stamm noted that θ_{IC}, the critical angle of total reflection, is sensitive to the difference in refractive indexes at interfaces. In this way, by allowing incident radiation or particle impinge upon a surface at small angles, a sensitive measure of the nature of free polymer surfaces and buried polymer interfaces may be obtained. Analysis of interference patterns allows accurate (0.2 nm) determination of thickness of layered structures. Another important parameter that emerges from this analysis is σ, the mean deviation in measurement of thickness which gives a measure of interface roughness. The depth resolution depends on the nature of the incident radiation: xrays - 1 nm; neutrons - 10 nm. Lateral resolution is about 1μm.

One of the important and difficult to measure features of polymer blends is the nature of the polymer-polymer interface. Characterizing this interface for a particular pair of polymers is important because the physical and mechanical properties of the blend are critically dependent on the nature of the interaction. A pair of polymers may be miscible, immiscible, or partially miscible. Most high molecular weight polymers are immiscible (see Figure 1a, wherein differing polymer chains are represented by lines of different thicknesses). However, a pair of polymers that is nominally immiscible may display partial chain mixing or swelling at an interface. A gradient of composition may result as shown in Figure 1b.

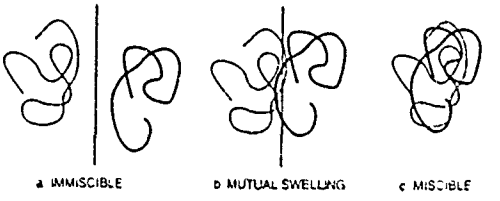

Figure 1. Polymer-polymer interface.

To study the interdiffusion of polymers, very smooth films were prepared by spin coating one polymer then picking up a second polymer from a film on water. In this way, Stamm evaluated interdiffusion or welding of polymers as a function of time and/or temperature. Thus in one study, polystyrene (PS) on glass was overcoated with bromopolystyrene. This polymer pair is incompatible at ambient temperature, but measurement of σ as a function of temperature revealed that intermixing of the polymer layers occurs starting at the glass transition temperature (T_g) of PS (ca. 103°C). Interphase thickness increases with continued increase in temperature.

Dr. R.A.L. Jones, Cavendish Laboratory, Cambridge, U.K., lectured on forward recoil elastic scattering (FRES) of polymer surfaces and thin films. In this technique, also known as Rutherford backscattering (RBS), a source of particles is directed at the sample normal to the surface. Backscattering (usually of neutrons) is a function of atomic number. From this technique, elemental composition as a function of depth is obtainable as different atoms have different cross sections for scattering depending on atomic number. Identical atoms in different chemical environments cannot be differentiated. Depth resolution at normal incidence is 300 Å.

Jones noted that in a miscible blend of polymer A and B, one polymer often has a lower surface energy which can lead to surface directed spinodal decomposition as shown schematically in Figure 2 where the ordinate is Φ_A (the weight fraction of polymer A, and the abscissa represent a distance scale). Thus, if the surface is rich in polymer A, some region adjacent to the surface will be poor in polymer A. This compositional oscillation will extend from the surface in a damped fashion until bulk homogeneous composition is reached.

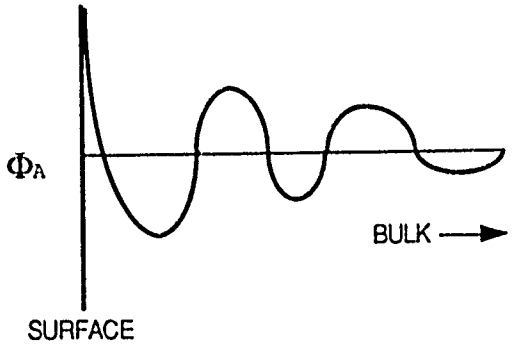

Figure 2. Miscible blend of polymer A and B showing directed spinodal decomposition.

This technique was applied to the barely immiscible blend of poly(ethyenepropylene) (PEP) and its deuterated analog (d-PEP). Analysis of quenched melts for deuterium as a function of depth shows the surface enriched in d-PEP, which has a slightly lower surface energy than PEP. This enrichment oscillates in a manner similar to that shown in Figure 2, with the oscillation period becoming longer (phase separation becoming more pronounced) as a function of thermal aging.

Professor M.J. Miles, H.H. Wills Physics Laboratory, Bristol University, U.K., gave a presentation on the application of scanning tunneling microscopy (STM) to polymer surfaces. The STM utilizes a sharp conducting probe The probe approaches to within 10 Å of the surface with an applied potential between the surface and the tip when the wave functions of this sharp tip and surface molecules overlap current flows.

For analysis by STM, most organic materials (which are not conducting) must be deposited on a conducting substrate; e.g., highly ordered pyrolytic graphite (HOPG). Because of this requirement and because high molecular weight polymers are usually only semicrystalline at best, STM of synthetic organic polymers has been minimally successful. Another difficulty with organic polymers is lack of dimensional stability to the traversing tip, which often literally pushes the molecule along the surface so that it is not observed on rescanning.

Long chain hydrocarbons (such as $C_{36}H_{74}$ which is related to polyethylene) were adsorbed on HOPG and examined by STM. At low resolution light and dark areas corresponding to proximate, incommensurate lattices are seen. Individual chains are discernable at high resolution.

Because of the tendency to form ordered helices, biopolymers such as DNA and poly(benzyl-l-glutamate) can be imaged on suitable substrates. A carbon mirror that is flat to 2 Å has been successfully utilized as a substrate.

Synthesis/Design

Important efforts in synthesis aimed at modifying polymer surfaces was evident in this group of presentations. This research is aimed at utilizing organic and polymer chemistry to introduce specific functionality and to create a complex structure wherein the substrate offers properties complemented by those of the surface modified layer.

Professor T.J. McCarthy, Polymer Science and Engineering Department, University of Massachusetts, Amherst, described the surface modification of several polymers studied by microbalance, ESCA, and contact angle measurements. As an example, it was found that poly(vinylidene fluoride) (PVF_2) could be dehydrohalogenated by tetrabutylammonium hydroxide in water (Figure 3). In this reaction, the tetrabutylammonium cation acts as a mediator for the reaction, as PVF_2 is unreactive with aqueous bases such as sodium hydroxide.

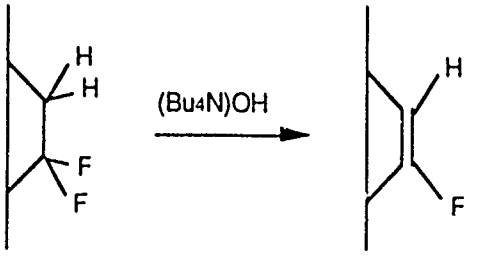

Figure 3. Dehydrohalogenation of poly(vinylidene fluoride by tetrabutylammonium hydroxide in water.

When oil and water are mixed, the oil comes to the surface of the water immediately because both fluids are low viscosity and equilibrium is established rapidly. With long polymer chains, equilibrium is established very slowly because of high viscosity (even in the melt). Professor Phillip Pincus, University of California, Santa Barbara, emphasized this point in a summary lecture He noted that chain motion is constrained by the presence of

surrounding chains which accounts for extremely slow dynamics. This point was illustrated by McCarthy's results with end functionalized PS. With a number average molecular weight of 10,000, PS was modified by adding a small amount of polystyrene end functionalized with ($-C(O)O(CF_2)_8CF_3$). The cast film has an initial surface energy similar to PS. By angle-resolved ESCA, which at a take-off angle of 15° interrogates the composition of ca. the top 10 Å, it was shown that annealing above T_g eventually results in a highly phase-segregated, fluorocarbon-like surface

Professor Bengt Rånby, Department of Polymer Technology, The Royal Institute of Technology, Stockholm, described photochemical methods of modifying polymer surfaces. His most recent results concern a continuous method in which fibers are first drawn through a presoaking solution of photoinitiator; e.g., benzophenone and a reactive vinyl monomer in acetone solution, then into a reaction chamber where irradiation causes photoinitiated grafting of the monomer on the polymer substrate. The inability to extract the majority of the grafted polymer with good solvents indicates the grafted layer is chemically bonded to the surface.

The importance of this research is illustrated by the modification of high-density polyethylene (HDPE) fibers. For example, fibers available commercially, such as Hoechst-Celenese "Spectra" fibers, have exceedingly high specific modulus—much higher than steel. Because of high crystallinity and lack of surface functionality, the fibers adhere poorly to composite matrices such as epoxies. However, adhesion of HDPE to epoxy resins is strongly affected by grafting. For example, grafting of acrylamide on HDPE increases the adhesion to epoxy resin about 5 times.

Professor Graeme George, Department of Chemistry, University of Queensland, Brisbane, Australia, described a similar approach to surface modification of fibers by photochemically initiated polymerization at the surface. In this way, he affected control of fiber surface properties, controlling strength and toughness of the resulting fiber reinforced composite by balancing load transfer and crack deflection by debonding.

Summary

In his summary lecture, Prof. Pincus gave introductory remarks about polymer properties pertinent to surface properties and encapsulated his view of "what we know, and what we don't know" about polymer surfaces. He noted that polymer surface interactions are often unexpectedly strong. Although the interaction of each monomer may be small, the high number of contacts caused by high number of monomers in a chain can lead to irreversible adsorption. He recognized the difficulty of chemical surface control by synthesis and processing and discussed the interplay of kinetics and thermodynamics in determining final polymer properties. Prof. Pincus said there are exciting challenges and opportunities in surface polymer science, which is highly relevant to the use and lifetime reliability of polymeric materials. He supported the researchers in this area and recognized the importance of their pioneering work.

Conference on Diamond, Diamond-like, and Related Coatings

by Max N. Yoder, Electronics Division, Office of Naval Research, Arlington, Virginia.

Introduction

Although labeled a European conference and held in Nice, France, this meeting was international with representatives from virtually all the countries in the world currently exploring the nucleation, growth, and applications of artifact diamond. Representatives from Japan, the former U.S.S.R., and the U.S. accounted for over a third of the attendance. In contrast to the first European conference held in 1990, this conference was clearly dominated by diamond rather than diamond-like films. The most significant aspect of the conference was that several groups have now confirmed that artifact diamond films can be nucleated and grown without using molecular hydrogen gas. Eliminating hydrogen gas not only significantly reduces the cost of diamond growth, but also clearly reduces the danger of explosion.

Artifact Diamond Films

The first of these confirmations was from conference chairman Peter Bachman, Philips Research Laboratories, Aachen, FRG. In his paper entitled "Exploring the C/H/O Phase Diagram of Diamond CVD," he described the use of acetone-oxygen gas mixtures without additional hydrogen added to the microwave plasma chemical vapor deposition (CVD) gas phase. He continued to refine the "Bachman Magic Wedge" of the C/H/O phase diagram. He has now shown that the lower limit (C) is lower than originally thought. This limit (as explained by John Angus of Case Western Reserve University, Cleveland, Ohio) results from the solubility of carbon in an H/O gas. The upper limit was also modified in that it is no longer a straight line, but as H:O ratios become < 1, its carbon magnitude is reduced. Angus explained that this was because of the supersaturation limit of carbon in an H/O gas. Dr. Bachman has noted that the highest diamond growth rate occurs when the H:O ratio is 1:1, but has also shown that diamond may be grown from a mixture of 5 percent molecular hydrogen in carbon monoxide

In a paper entitled "Influence of Gas Phase Parameters on the Deposition Kinetics and Morphology of Thin Diamond Films" by R. Beckmann et al., Institute of Technical Physics, University of Kassel, FRG, he noted the growth of high-quality diamond occurred using either pure CH4 or methanol. However, the growth rate did not exceed 0.05 μm/hour.

In a poster paper entitled "Radio Frequency Hot Filament CVD of Diamond" by S. Mitura, Technical University of Lodz, Poland, diamond was deposited when both a hot filament and a radio frequency (R.F.) field were used with a feedstock of methane only. In the absence of the R.F. field, only amorphous carbon was deposited.

Chen et al., National Chiao-Tung University of Tiawan, presented a paper entitled "Growth of Diamond From CO^2-(C^2H^2, CH^4) Gas Systems (II) Effect of Hydrogen Addition." He showed that although diamond could be growth without introducing molecular hydrogen gas, its addition up to 5 percent mole fraction not only improved the quality of the resulting diamond, but also increased the growth rate. This was a follow-up to a paper presented earlier this year at the Society of Photo-Optical Instrumentation Engineers (S.P.I.E.) meeting in San Diego.

Dr. J. Narayan, National Science Foundation, presented a paper entitled "Novel Methods for Processing and Properties of Diamond Thin Films." This was a follow-up to his controversial paper that appeared in the April 19, 1991, issue of *SCIENCE*. The process described is allegedly totally free of hydrogen in any form. The process relies on the fact that carbon has virtually no solid solubility in copper, and that copper has a lattice constant just greater than 1 percent of that of diamond. The process implants a 10^{18}/cm^3, 60-kV dose of carbon into copper and then irradiates it with a XeCl laser (0.308-μm wavelength) pulse of 45-ns duration at 5-Joules/cm^2 energy level during which the copper reaches a temperature of 2400 K. This creates a melt depth of 900 nm. The rapid quenching is said to lead to the formation of a diamond layer some 50-nm thick. Information supplied here (but not in the previous issue in *SCIENCE*) was that the diamond formation occurs some 20 nm beneath the surface of the copper. The overlying copper must be removed by etching in dilute nitric acid. Then diamond with a 1332-cm-1 Raman signal exhibiting a 5-cm-1 full width at half maximum (FWHM) may be observed.

Coincident with this meeting was a press release by the Research Triangle Institute of North Carolina. The release described another diamond growth process somewhat similar to that reported by Beckmann. The difference being a radio frequency (13.5 MHz) plasma was created solely from the liquid sources of methanol and water. By adjusting the dilution of the methanol in water, the C/H/O ratio can be better controlled and the growth rate increased to approximately 1 μm/hr. These liquid feedstocks may be obtained cheaply and in very high purities.

Electronic Applications of Diamond

The *holy grail* of single crystalline diamond grown on nondiamond substrates has not yet arrived. However, three papers described approaches that may lead to highly oriented material acceptable for certain electronic applications of diamond.

Peter Koidl of Fraunhofer Institut für Angewandte Festkorperphysik of Freiburg, FRG, presented the opening paper of the conference (coauthored by C. Wild) entitled "Assessment of Polycrystalline Diamond films in Optics." He showed *inter alia* that polycrystalline diamond films (once nucleated) could be grown with predominately [100] growth faces if the CH^4 dilution in H^2 was increased from 1 percent for nucleation to about 4 percent during growth. In such a mixture, the [100] growth face becomes predominate as the fastest growth proceeds on the [110] step edges of the slightly vicinal [100] crystal faces. After several hundred μm of growth, the structure becomes columnar with the x-ray rocking curves indicating that the diamond columnar structure is within 2 degrees of the [100] crystallographic direction.

In "Textures and Morphologies of CVD Diamond," R. E. Clausing et al., Oak Ridge National Laboratories, Tennessee, described similar results and attributed them to van der Drifts "principle of evolutionary selection." This paper showed that films free of twins, microtwins, and stacking faults are deposited when only the [100] facets are permitted to grow. In a companion poster paper entitled "Microtwin-Growth Facet Correlations in As-Grown CVD Diamond Films by TEM," the same authors described the novel transmission electron microscopy (TEM) used to characterize the twin-free films.

The culmination of the art of oriented diamond crystalline growth was presented by Michael Geis, Massachusetts Institute of Technology, Lincoln Laboratories, in "Diamond Transistor Performance and Fabrication." This work exploits the phenomenon that small sub-micron-sized diamond particles, when placed on virtually any smooth surface, align their crystallographic axes such that the [111] axis is normal to that smooth surface. His exploitation proceeds as follows: a checkerboard matrix of anisotropically etched inverted pyramids on 100-μm centers is fabricated on [100] oriented single crystalline silicon. When these inverted pyramid "holes" are "seeded" with diamond particles, the diamond particles align so that their [111] axis is normal to the smooth pyramidal walls. This assures that their [100] axis is normal to the silicon surface and parallel to the silicon [100] axis. Since the holes are anisotropically etched in the silicon, the "in-plane" axes are also orientated. A diamond film is grown on the oriented diamond particulate seeds; eventually, the film coalesces to become continuous. The

initial particulate seeds are of varying sizes and the initial resulting film is therefore not smooth. However, it does eventually smooth out after several hundred micrometers of growth because the [110] step edges grow much faster than the [100] surface. Thus while film thickness over a very small seed is initially thinner than that of that over adjacent neighbors, the fast growing [110] edges presented by the adjacent neighbors eventually insure that the film is smooth. The corollary to this is that the immediate precursor radicals for diamond growth (whatever they may be) exhibit finite surface migration velocity (mobility). In contrast to those films grown from random seeding by the principle of evolutionary selection, the films grown from the oriented seeds exhibit a 0.2-degree spread in the x-ray rocking curves. This small spread is demonstrated not only in the direction normal to the surface, but also inplane. Dr. Geis also provided details on transistors made from homoepitaxially grown diamond and on his new negative electron affinity diamond cold cathodes that exhibit current densities as high as 2 amps/cm^2. The robust nature of these diamond cold cathodes enable them to be exposed to atomic oxygen, hydrogen, air, and/or water (a process normally fatal to all other types of cathodes) without degrading their properties.

W.M. Lau et al., The University of Western Ontario, Canada (with authors from Eastman Kodak), demonstrated negative results in attempting to duplicate the work of J.F. Prins of the Schonland Research Center for Nuclear Sciences University of Witwaterstrand, Johannesburg, Union of South Africa, in which single crystalline diamond was allegedly made from implanting carbon into hot copper. (Subsequent reports from Prins have authenticated diamond by both electron energy loss spectroscopy and transmission electron microscopy.)

Other Significant Presentations

While there were no other significant themes, there were several other significant papers. Professor R. Clarke et al., University of Michigan (with authors from General Motors Research Laboratories), presented a paper entitled "New Developments in the Growth of Epitaxial Boron Nitride and Diamond Films on Silicon." Although portions of this work employing the physical vapor deposition of cubic boron nitride (cBN) was previously published, new results indicate that the maximum pseudomorphic limit of single crystalline cBN on silicon is 20 nm, and that a similar 20-nm pseudomorphic limit of diamond on cBN may exist.

T. Inuzuka, University of Chitosedai, Tokyo, Japan, presented a paper entitled "Epitaxial Growth of Diamond Thin Films on Foreign Substrates." He showed that diamond growth on cBN proceeded by Volmer-Weber type mechanisms in which islands would form.

H.G. Bussman et al., Freiburger Material-forschungszentrum, FRG, presented the first paper using supersonic expansion— "Preparation of CVD Diamond films by a Pulsed High Pressure Valve and Hot Filaments." This work exploits the ability to flow a small percentage of heavy molecules (e.g., CH^4) in a lighter gas (e.g., hydrogen) at speeds equal to that of the lighter gas molecules. Using a 1-percent mixture of methane in hydrogen, 8-bar stagnation pressure, 5Hz-pulse frequency, and a 180-ms pulse duration, growth rates were achieved up to 2.3 times faster than those with constant gas flow. Under these conditions, the impact velocity of the CH^4 could be sufficient to cause molecular decomposition.

M. Ihara et al., University of Tokyo, Tokyo, Japan, presented a paper entitled "Low-Temperature Deposition of Diamond at 135°C." He described a tantalum hot filament system in which high-quality diamond could be grown at very low substrate temperatures provided that the methane concentration in hydrogen was reduced to a very small fraction of 1 percent (with commensurately slow growth rates).

In a late entitled "Diamond Nucleation on Highly Oriented Pyrolithic Graphite," Professor J. Angus, Case Western Reserve University, demonstrated that diamond nucleates exceptionally well on the prism edges (e.g., not the basal plane surface) of graphite. Even more amazing, he provided evidence that the graphite is actually transformed into diamond in the presence of both C^2H^2 and CH^3. A paper entitled "Catalytic Effects on Plasma Assisted Chemical Vapor Deposition (PACVD) Diamond Film Formation" by W. Brower and R. Bauer of Marquette University, Milwaukee, Wisconsin, (with N. Sbrockey, Eaton Corporation) showed that palladium catalysis was effective in nucleating diamond. This was particularly so in conjunction with pyrolytic graphite. (It should be remembered that palladium has a great capacity to getter and release hydrogen.)

Several plasma jet papers were presented. E. Pfender et al., University of Minnesota, presented a paper entitled "Rapid Synthesis of Diamond by Counter Flow Liquid Injection into an Atmospheric Pressure Plasma Jet." In this paper, an atmospheric pressure 16-kW, 400-amp, 40-V DC jet was injected with liquid alcohols, ketones, halogenated compounds, and/or aromatic compounds. Deposition rates of up to 1 mm/hr were achieved at 1000°C substrate temperatures when using acetone and ethyl alcohol. X-ray diffraction results indicated that diamond was the only crystalline phase of carbon present. G. Lu et al., Norton Company, Northboro, Massachusetts, provided data showing that their plasma jet system deposited polycrystalline diamond having a maximum thermal conductivity at 220 K versus 77 K found in most diamond. Thermal conductivity was 12 W/cm -K. They deposit about 1 carat/hr which over a 6" diameter leads to 20-μm thickness.

Other plasma jet deposition poster papers were given by various authors, but with no noticeably significant advances. The efficacy of the plasma torches (and the acetylene torches) lies in the high Peclet number (ratio of convective to diffusive mass flow) that they are able to achieve. D.K. Smith et al., Applied Science and Technology, Inc. of Woburn, Massachusetts, demonstrated another approach to achieving a higher Peclet number in a paper entitled "Large Area Diamond Reactor Using a High Flow Velocity Microwave Plasma Jet." This is a new recirculating gas reactor with a Peclet number of 100 and operates between 24 and 200 Torr. Inasmuch as it is a microwave plasma-driven system, it does not operate at atmospheric pressure. Nevertheless, it exhibits gas velocity increases of 10,000 over that of most microwave plasma systems. Its prime advantage, however, is the great reduction in expended hydrogen gas. (With the advent of the new molecular, hydrogen-free systems, it will be interesting to see if this approach will endure). With the high Peclet numbers, the lifetime of the atomic hydrogen and the hydrocarbon radicals appears to be longer such that the flux can be drifted further and larger area surfaces grown upon.

Several papers on diamond characterization were presented. In a paper by R. Kalish et al., Israel Institute of Technology Haifa, Israel, entitled "Electron Spectroscopies for the Assessment of Damage in Diamond," a truly new technique emerged. This paper described a new low-energy secondary electron emission (SEE) spectroscopy in which the secondary electron yield for diamond approaches unity. On the other hand, the secondary electron yield for other forms of carbon does not exceed 0.65. The SEE's ability to distinguish between diamond and non-diamond carbon was shown to be more distinctive than electron energy loss spectroscopy (EELS) or Auger spectroscopy. Several papers noted the difficulty to detect the presence of atomic nitrogen in diamond unless it is complicated with defects or other impurities. Ironically, the presence of nitrogen with its deep level charge carrier traps in diamond that is currently the biggest problem in achieving high-performance diamond devices.

T. Anthony et al., in a paper entitled "Properties and Applications of Diamond with Varying Isotopic Composition," provided the remaining conclusive evidence that Umklapp scattering is truly the cause of natural diamond not being a better thermal conductor. Previously, it was still considered possible that the high-thermal conductivities exhibited by nearly 13C-free diamond could have resulted from the crystal perfection achieved as depicted from FWHM Raman signals of 1.7 cm-1. This paper provided thermal conductivity as a function of isotopic mole fraction for the entire spectrum from nearly pure 12C to nearly pure 13C. At purities greater than 99 percent at either extreme, the thermal conductivity increased above that of natural diamond (with its intrinsic 1 percent 13C impurity ratio). At isotopic impurity ratios between 2 percent and 98 percent, thermal conductivity varied little and was less than that of natural diamond. The threshold for laser damage to the isotopically pure diamond was 10 times higher than for natural diamond. It was speculated that the narrower phonon spectrum resulting from the isotopically purer material provided less coupling to the incident optical source. In addition, the greater thermal conductivity of the isotopically pure material would provide less probability of a localized hot spot.

Final Comment

Although several papers were presented, 39 printed abstracts were either withdrawn or failed to appear at the meeting. Many of these were from the Far East—particularly from the Peoples Republic of China. One no-show paper was an invited paper by S. Ogale, University of Puma, Poona, India, in which he allegedly places pyrolytic graphite in a beaker full of benzene. After irradiating it with a laser, the graphite surface turned to diamond.

Addendum

The following information was provided by Charles A. Hewett, Naval Command, Control and Ocean Surveillance Center (NOSC), San Diego. The information focuses on electronic device fabrication on diamond.

D.L. Dreifus, Kobe Steel Research Laboratories, reported the first demonstration of field-effect transistor fabricated on polycrystalline diamond thin films. These films were first planarized by polishing and then implanted with a high dose (3.5×10^{16} cm^{-2}, 60keV) of boron to create a p-type channel layer. The boron was activated with a 1200°C, 30-min anneal. The surface was subsequently etched to remove any graphitic surface component. The gate oxide was a 750-Å thick SiO_2 layer deposited by CVD. The device structure was of the concentric ring type, with a gate length of 5 μm and a gate width of 314 μm. The gate metal was aluminum (2000 Å), and the source and drain ohmic contacts were gold films (2000 Å). Several of these devices showed modulation of their channel conductance, with measured transconductances of up to 121 μS/mm. This is the highest transconductance reported to date for a diamond MISFET device.

N. Fujimoto, Sumitomo Electric Industries, Ltd., reported on MESFET device fabrication on epitaxial diamond films. These films were boron-doped, homo-epitaxial films grown on diamond substrates with a (100) orientation. Aluminum was used to form Schottky contacts, with good rectification obtained for films grown with 6 percent methane in the reactant gas. The rectifying behavior was further improved by using a non-doped diamond layer between the aluminum Schottky electrode and the boron-doped diamond film. To fabricate the MESFET device, a boron-doped ($1x10^{18}$ cm^{-3}) layer 0.8-μm thick was grown on an insulating diamond substrate. Tungsten source and drain contacts were then deposited. The tungsten contacts then acted as a mask material to allow selective growth of the non-doped diamond layer (0.5-1.0μm). An aluminum gate was then deposited on the undoped layer. These devices (also of the concentric ring type) were operated at temperatures of up to 300°C.

The work of C. Hewett and J. Zeidler, NOSC, showed that ohmic contacts with low specific contact resistivities (10^{-5} Ω-cm2) can be easily formed on highly doped diamond films. In addition a tri-level boron implantation scheme was used to create a uniformly doped p-type layer in natural type IIa diamond. This layer was then used to fabricate a MISFET device, again with a circular geometry. The current-voltage characteristics clearly show current saturation and complete channel pinch off. This was the first demonstration of a planar device with those particular characteristics.

An interesting poster paper by V. Varichenko et al., Byelorussian State University, demonstrated the fabrication of a rectifying junction and a unipolar transistor based on a p+ -i junction. Natural diamonds were used, with the p+ regions created by boron ion implantation.

M. Werner, Technical University of Berlin, reported on a polycrystalline diamond thermistor. This device consisted of a p-type silicon substrate, an undoped polycrystalline diamond film, and a boron-doped (10^{21} cm^{-3}) polycrystalline diamond film. The ohmic contacts consisted of sputter-deposited aluminum contacts (contact resistivity = 10^{5} Ω-cm^{2}). The advantages cited for this type of device include a high-temperature sensitivity[1], good temperature stability, a large measurement range, immunity to ambients, a short response time, and an inexpensive production process based on conventional photolithography and reactive ion etching.

Two papers dealt with the use of diamond films in the fabrication of ionizing radiation detectors. One of these, a poster session paper by I.M. Kotina et al., Nuclear Physics Institute, Leningrad, showed that a surface barrier detector based on heterostructure of p-type silicon and hydrogenated amorphous carbon could be used to fabricate a detector with an alpha particle resolution at 5 MeV of 16 keV, and suggested the possibility for a position-sensitive detector based on this type of structure. The second paper, an oral presentation by D. Kania, Lawrence Livermore National Laboratory, was aimed at producing diamond film ionizing radiation detectors (with diamond as the active material) for an experiment at the Superconducting Supercollider. Prototype detectors were fabricated from type IIa natural diamonds. The average distance traveled by free carriers in the material, **d**, was determined in these natural diamonds and in CVD diamond films in an attempt to correlate **d** with the CVD growth conditions.

A further application of the diamond/silicon heterostructure is the heterojunction bipolar transistor (HBT), where the current gain is exponentially dependent on the difference in the bandgap energies. With diamond having an energy bandgap of 5.5 eV and silicon an energy bandgap of 1.1 eV, the potential for very high gain amplification is apparent (assuming that the bandgaps can be properly tailored). A poster paper by D. Jeng (now at AT&T Bell Laboratories) attempted to characterize the junction using current-voltage measurements. It was concluded that the use of Schottky contacts (Al) mask the effect of the heterojunction, but that the use of ohmic contacts (Pd) allow the heterojunction to be clearly observed. "Double-kinks" in the current voltage characteristics were attributed to either band bending or tunneling at the interface, or perhaps a combination of the two.

[1] It should be noted that high sensitivity requires low doping

National Science Foundation Contributions

Royal Society/Fellowship of Engineers Analyzes Science and Technology Issues

by C.T. Owens, National Science Foundation European representative.

The Royal Society and Fellowship of Engineers in the U.K. have a small staff that analyzes issues involving science and technology (S&T). These organizations are private, honorary, and learned organizations that also receive public funding. The public funding for the most part is further distributed to the research community to support research and international travel, and to purchase equipment. The Science and Engineering Policy Unit (SEPSU) is a small research organ of these organizations. The staff is small (three professional, three clerical, plus a director); it is building a reputation for assisting the policy debate in S&T-related issues in the U.K.

Established in 1986, SEPSU receives its basic money from nongovernment sources. By providing good data on important issues, SEPSU tries to carry out independent and objective studies that will improve the S&T policy debate in the U.K.

A management board, including senior civil servants, scientists, and Director, Dr. Peter Collins, manages SEPSU. The management board is concerned with both quality control and management issues. Projects may be self-initiated by SEPSU staff or undertaken on the basis of requests from government agencies and other organizations interested in science policy issues. Typically, SEPSU will first prepare a preproposal indicating how it would approach the sponsor's request. If that approach seems appropriate, a full proposal is prepared, including cost information and greater detail on the research plan. Professional staff time plus travel outside the U.K. costs £300 per day.

For more information, the following reports are available.

- Evaluation of National Performance in Basic Research (1986)
- Migration of Scientists and Engineers to and from the U.K. (1987) - SEPSU policy study #1
- Collaboration in Science and Technology Between the U.K. and Japan (1988) - SEPSU policy study #2
- European Collaboration in Science and Technology:II. Pointers to the Future for Policy Makers (1989) - SEPSU policy study #3
- European Collaboration in Science and Technology: A Guide for the U.K. Scientist and Engineer (1990)
- The Structure of Research Expenditure (1990) - SEPSU policy study #4
- Quantitative Assessment of Departmental Research. A Survey of Academics' Views (1991) - SEPSU policy study #5
- The Contract Research Business in the U.K. (1991) - SEPSU policy study #6
- Research Support for Young Investigators (1991) - SEPSU policy study #7.

The address for SEPSU is:

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London, U.K.
SW1 Y5AG
Tel: (071) 839-5561
FAX:(071) 930-2170

NSF/Europe Comment

The SEPSU is building a reputation for assisting the policy debate on science and technology-related issues in Britain. Productivity is increasing but still limited by a small staff.

Science Policy is Reorganized in Poland

by C.T. Owens.

Introduction

Serious budget cuts, opposition from some sectors of the scientific community, and growing pains of a new organization have slowed the flow of grant funds from the new State Committee for Scientific Research to Polish researchers. Nevertheless, the organization has made its first grants and enjoys significant support among researchers and Polish officialdom.

The visit to Poland of Dr. Frederick G. Bernthal, Deputy Director of the National Science Foundation (NSF), 8-10 October 1991, provided the opportunity to review developments in Polish science policy. In the last year, Poland has passed a new law and established new organizations to move the support for scientific research onto a merit-based system. While Dr. Bernthal's discussions with Polish counterparts covered a variety of issues, this report focuses on the science policy reform. Except where otherwise indicated, the views expressed are those of the Polish officials concerned.

Polish Academy of Sciences

The Vice President and Scientific Secretary of the Polish Academy of Sciences (PAS) is Leszek Kuznicki. Professor Miroslav J. Mossakowski is Director of the PAS Medical Research Centre in Warsaw.

The biggest change in science in Poland is represented by the State Committee for Scientific Research (Committee). The Committee is centralizing the support for science in one governmental organization—a move in the wrong direction[1]. The availability of research grant money has been reduced from 9.7 to 6.2 trillion Zlotys ($1 = about 11,000 Zlotys) because of national budget difficulties. The Committee bureaucracy moved more slowly and spent its funds at a rate slower than others in the national budget. Consequently, science suffered a 32-percent cut. If each institution had its own budget from the beginning, as before, the problem would not have occurred. Poland is too small a society to need a system involving such an extensive process to obtain a research grant; the good people are known.

Money for the PAS institutes (and other institutes) comes from both the Committee and in a direct budget allocation. Committee money pays for institutional overhead and for research grants and equipment. Funds for instruction of staff and foreign exchange for international cooperation also come from the Committee but these have not been distributed. Lack of money for international cooperation has made things difficult for the PAS, which has always had an role in international activities. The PAS provides money to purchase journals and books and to maintain collections of scientific materials.

Many people on the new Committee are involved in the decision making; this creates problems. Primarily, the research community elects the Committee members[2]. To decide on a grant application, the Committee president must have the approval of about 70 people. Under these circumstances, the PAS is now in the position of having management responsibility for its institutes without the power to provide the funds (11,000 people; 4,300 scientists). The PAS institutes are still much better off than most of the academic institutes.

The PAS is under attack. International cooperation for Polish science still depends on the PAS and the Ministry of Education, and it cannot be done by the Committee alone. The PAS should continue to have this responsibility even though the Committee is not yet interested in international matters.

[1]NSF/Europe comment: The new system requires that NAS research institutes, which used to obtain all of their funds from the PAS, compete for research funds from the Committee

[2]NSF/Europe comment: The Prime Minister also appoints several members.

State Committee for Scientific Research

Professor Witold Karczewski is the Chairman of the State Committee for Scientific Research.

Recently, the science budget was cut by 30 percent; this is not enough money. Despite the bad situation, it can be manageable if the institutions of research will make some adjustments. In the past, everyone got research money and no one was asked for results. However, now scientific value is the one thing considered in deciding on the distribution of research funds. Competition exists for the first time. Publication of scientific papers, *Science Citation Index*, and quality of the journal of publication are now being used as criteria for judging someone's work.

Two groups do not like the new procedures and the new situation: (1) top management of the PAS and (2) poor scientists. In the past, the PAS acted like a "ministry for the basic sciences." This will no longer be possible. Seventy percent of Poland's researchers are located in the universities. Money must go to the researchers doing good work rather than to specific institutions. So the institutes of PAS can no longer take their funding for granted. On the other hand, the U.S. must build up centers of excellence in universities and polytechnics in various parts of the country. This means that researchers in these institutions who are doing good work must receive good funding.

Under the Communist regime, industry, universities, and PAS were kept quite separate as a technique of dividing and controlling the intelligentsia. The Committee and its management consists of researchers from all sectors; the Committee has no research institutions. More and more scientists support the idea of the Committee. The system will still work if the management remains strong.

Ministry of National Education

Professor Robert Glebocki is Minister of National Education (MNE). Professor Roman Duda is Deputy Minister of National Education, and Dr. Jerzy A. Gasiorowski is Director of the Department of Science and Higher Education.

Poland has 10 universities and 18 technical universities, plus about 100 academies that specialize in engineering, teacher training, agriculture, medicine, art, and sports. The Ministry of Health and Social Policy supervises the medical academies, but all of the money goes to them via the MNE. The universities have a great deal of autonomy. Consequently, the many changes in the curriculum (such as Economics) made necessary by the political changes are going very slowly.

The money provided to the educational institutions is for educational purposes rather than for research. However, money for Ph.D. work comes from the MNE. Also, funds (along with other sources) for the research necessary to obtain the Doc. Hab. degree come from the MNE. The main source of funds for research is from the Committee for Scientific Research. Industry supports very little now (down from around 30 percent in the 1970s). Some foundations provide a small amount for research to universities.

Universities and PAS institutes employ 72 and about 7 percent of researchers, respectively. The new procedures for the management of research funds in Poland are aimed at diminishing PAS's policy role. Even though the president of PAS currently is Undersecretary of State, PAS cannot be a ministry. There should be a closer collaboration between PAS institutes and universities. There are some collaborations now (such as the PAS Institute for Physiology and Biochemistry and Warsaw University) but this should be expanded. Poland cannot afford to support scientific institutes not involved with students. The funding of the PAS institutes via the State Committee for Scientific Research is a good thing, and the Ministry of National Education is in favor of the Committee. The PAS researchers who teach at a university will receive academic titles such as professorships.

While Poland has not been accepted into the European Community, it is receiving support from programs of the Commission of the European Communities. The TEMPUS program has supported 500 Polish students during studies abroad plus 65 joint research projects with universities in Western Europe. European Currency Units (ECU) 200 million have been made available to Poland; ECU 15 million has been for TEMPUS. Increases will be necessary to get new activities underway this year. Specifically, ECU 3-4 million is needed in this second year of what will likely be a 3-year program. But this has not happened yet. The number of students going to the West will diminish to about 100 this year.

The biggest education task for Poland is to prepare as many good teachers as possible as soon as possible. About 150,000 teachers need to be produced using new ways that replace the old Communist system. Also, it will be necessary to help the country's second-tier universities to become centers of excellence so they can cooperate with the world. It will be helpful if the U.S. and other countries look beyond Warsaw for some of their contacts and cooperation with Polish universities.

NSF/Europe Comment

The advent of the State Committee for Scientific Research and the requirement for all researchers to seek their research funds from it are having an impact. As reflected above, the view held on the workings of the Committee is dependent upon how one's activities are affected by it. With the exception of PAS, people in research and those working in science policy generally support the Committee's objectives. Clearly, there are growing pains involved in processing proposals and in making timely decisions. Despite the funding delays, the reduced budget for science and the daunting list of things that need to be done there is a shared recognition that the reform is fundamental to progress is Polish science.

The PAS cannot be expected to cheerfully embrace the erosion of its power. However, the likelihood is that PAS institutes will stray further away from their traditional isolated splendor as they become more involved with teaching as well as research, and in the new necessity to compete for research funds. As the PAS management points out, the Polish scientific community is relatively small. Professor Karczewski worked at a PAS institute (Medical Research Centre, Warsaw). Although it may not come easily, an accommodation with the new system seems likely as its effects take hold. Of course, this assumes that the Polish economy and the budget for science are sufficiently robust to give the new system a good chance to be recognized.

France Cooperates with Central and Eastern Europe in Science and Technology

by C.T. Owens.

Introduction

The French Government set up a series of programs for scientific cooperation with Central and Eastern Europe, to be coordinated by an interministerial organization known as MICECO, in April 1990. This report is based on a resume of the first 18 months (July 1990-end 1991) of operation of the programs. The resume was furnished to me by Prof. Henry Durand, Advisor to the Ministry of Research and Technology (MRT) for Central and Eastern Europe. The budget for this activity comes from several French ministries, and totals about $19 million.

Specific Programs

The most important program is that which provides fellowships for senior researchers and postdocs. This is separate from the student fellowship program managed by the Ministry of Education. The senior program provides fellowships of from 1 to 6 months, (average 4 months), and are nonrenewable. Table 1 shows percentages of fellowship recipients by country.

Table 1. Country of Origin of Fellowship Recipients

Country	Percent
USSR	37
Poland	22
Czech/Slovak	13
Hungary	10
Bulgana	7
Former German Democratic Republic	2
Yugoslavia	1

Candidates are nominated by French laboratories or other receiving organization, and chosen by an MRT panel that also includes representatives from MICECO and the Ministries of Foreign Affairs and Education. Selection criteria focus on the quality of both the candidate and the receiving laboratory. The postdoctoral fellowships are for from 6 to 12 months and may be divided. Selection criteria are much the same as for the seniors. The success rate is about 1 in 3, with 660 fellowships (321 seniors and 339 postdocs) out of about 2,000 applicants in the 18 months. Albania and the Baltic countries are eligible, but eastern Germany is not. Table 2 shows percentages of disciplines.

Table 2. Fellowships Discipline

Discipline	Percentage
Materials	35
Biology, Medicine, and Health	21
Mathematics/Information	16
Social Science/Humanities	13
Environment	6
Agronomy	6
Process Engineering	2

The BRITEST program was set up during 1991 as a way to allow researchers from the east to work in French industrial laboratories with cofinancing from the company involved and from MRT/MICECO. So far, a dozen awards have been made, and a campaign is underway in industry to promote this program.

Six "twinnings" of a French laboratory (or several) with a counterpart(s) in the East have been funded to allow cooperation in research over a relatively long period. A dozen "training/research" networks have been set up to assist graduate training via an exchange of researchers in a common research theme. Another 20 proposals in these two areas are under development.

The ACCESS program assists researchers from the East to attend scholarly meetings in France, based on nominations by the French conference organizers. So far, 665 researchers have come to France for meetings under this program.

The PARECO program pays for French researchers to attend meetings or summer schools organized (usually jointly) by a French organization and a local organization in the East. In 1990-91, this program financed 70 such visits.

Other related cooperative activities have included research on the process of transition of economic system underway in the East, including special fellowships for social scientists and humanities researchers. Training has been funded for specialists from Bulgaria, Czechoslovakia, and Hungary in science and technological information. An interdisciplinary social sciences/humanities center has been inaugurated in Prague, and computer equipment has been purchased. In Poland, a biotechnology project has been linked to a parallel French project, significantly strengthening both.

NSF/Europe Comment

At the end of 1990, French officials were predicting expenditures in the $10 million range for 1990-91; only half of what has actually been spent. The rapid collapse of the Soviet economy (and its ability to support such things as research) has added special urgency to programs of this kind in Europe. Reforms of science administration in Poland, Czechoslovakia, and Hungary are causing dislocations in those research communities as well, being played out against a backdrop of their own political and economic problems. Programs such as this French activity will provide some short-term symptomatic relief to some researchers. So far, there is no formula available for assistance to the East that promises to reach the best people on a scale that might stave off serious losses to these research communities.

Update on the French Programme Environnement

by Maria Casa, a State Department intern working at the National Science Foundation Europe Office.

Summary

The Centre National pour la Recherche Scientifique (National Center for Scientific Research [CNRS]) created the Interdisciplinary Environment Program. The goals are to encourage new research approaches to environmental issues, coordinate projects with private and public laboratories and universities, and serve as a clearing house for information on environmental research. After 1 year of operation, the administrative structure is in place but the program scope not clearly defined. Consequently, its scope many of the projects slated for 1991 have not started.

Introduction

This report is based on attendance at the CNRS-sponsored conference on environmental research at St. Malo, 8-9 October 1991 and CNRS publications (see sources). Also used were interviews of CNRS staff, including James Hiablot (Director of CNRS Interdisciplinary Programs), Claire Giraud (Americas Office), and Michelle Demanee (Information Office for the Programme Environnement).

Background

The Programme Environnement (PE) is one of seven interdisciplinary programs sponsored by the CNRS. In October 1990, the PE was created to encourage basic research relative to the environment (conducted by CNRS teams, as well as teams from other French or foreign institutions) and provide a framework for the coordination and integration of such research.

The PE is a continuation of CNRS' Program for Interdisciplinary Research on Environment (PIREN). In 1979, PIREN was established in response to growing French awareness of environmental concerns. For 10 years this program identified environmental risks and defined them in terms that could be dealt with scientifically. Studies by PIREN included such topics as

- Law and economy in the environment
- Historical approaches to environmental problems
- Systems analyses of continental waters and coastal and rural zones
- Global changes and their influence on ecosystems.

The PIREN was considered a success in coordinating interdisciplinary research within CNRS. Also, it successfully influenced the French scientific community about the importance of engaging in research relevant to the environment. The PE was founded to carry on with research initiated under PIREN, as well as to network. In addition, it was to develop and broaden relations with other organizations engaging in environmental research in France and abroad. Hopefully, CNRS researchers will begin participating in cooperative activities with environmental non-governmental organizations, universities, and other laboratories around the world.

Administrative Structure

The PE is guided by an Executive Committee (Comite d'Administration) composed of the Directors from CNRS' seven scientific departments and chaired by the CNRS Director-General. This committee is responsible for outlining a 3-year program and, upon recommendations from the Programs Committee (Comite de Programme), making budget allocations. The Programs Committee is composed of 15 members—7 are elected from the CNRS' National Committee[1] and 8 are appointed by the Director-General. The primary function is to recommend research topics and draw up calls for proposals.

The six scientific committees are responsible for evaluation of the research proposals submitted in answer to calls for proposals. These committees do not have a permanent staff. Members are appointed *ad hoc* in accordance with programs under way. They are chosen by the Director of the PE, and each committee includes one representative from the Ministry of Environment.

In keeping with its overall effort to encourage decentralization in research, the CNRS is also planning to establish four regional centers (Poles Regionaux) in affiliation with the PE. These area-specific centers of research are to be distributed as follows:

- Rennes - Research on the effects of environment on agriculture and polar research
- Strasbourg - Continental research
- Lyon - Rhone-Alp research
- Montpelier - Mediterranean research.

The regional centers will p omote participation at local and regional levels. Hopefully, this will increase scientific and public interest in environmental issues.

[1]The Comite National is the most important advisory body at CNRS. The committee combines some of the policy debate functions of a board of directors with research evaluation functions of disciplinary review panels and personnel selection and promotion functions of management officials.

Budget

The PE's budget is derived, for the most part, from CNRS' scientific departments. Of the seven disciplinary departments, only the Department of Mathematics and Basic Physics does not make a contribution. The 1990 budget allotted to the PE from CNRS sources was FF 12.9 million ($2.250 million). The PE received an additional FF 2.4 million ($0.420 million) from outside sources (including the Ministry of Environment) for the same year. Budgetary allotments from the departments to the interdisciplinary programs are at the discretion of the individual department.

It should be noted that this budget is used for research expenses only. Salaries of CNRS employees are covered by other budgets. Outside researchers continue to be paid by their home institutions even when working on CNRS-related projects.

Meetings to Promote the Programme Environnment

Strasbourg 1990. The new PE has sponsored two organizational conferences since its inception. The first was held in Strasbourg in October 1990. There, it was decided to continue to emphasize areas of research in which PIREN had already initiated projects. Accordingly, the following seven interdisciplinary areas were targeted for research during 1991.

1. Atmospheric phase of biogeochemical cycles
2. Biospheric aspects of hydrological cycle
3. Integrated systems: functioning and evolution of forest systems and herbaceous environments according to anthropic actions; interactions among systems, atmospheric phases, global changes
4. Functioning, disturbances, regulation of rural systems
5. Geographic units and experimental devices
6. Environment and development
7. Methods, models, and theories.

Planning for 1991 seems to have been a bit ambitious. To date, calls for proposals have only been issued for numbers 3, 4, 6, and 7 above. Proposals have been reviewed for numbers 6 and 7. Most of the 1991 budget, therefore, went to sustaining projects already initiated under PIREN rather than to launching new PE projects.

St. Malo 1991. The second PE Conference was held in St. Malo on 8-9 October 1991. One year after the Strasbourg symposium, the objectives were to review the operation of the PE and define the main line of scientific programming for 1992 and 1993.

Conference activities began with a general assembly during which opening remarks were heard from the Director General of the CNRS (Francois Kourilsky) as well as the Director and Deputy Director of the PE (Alain Ruellan and Alain Pave). Themes stressed were

- Need to decentralize research
- Need to establish links with other like organizations, both international and national, including non-governmental organizations, universities, and industry
- Difficulty of the "double integration" of social and natural sciences.

Concerns about raising the standing of environmental science to that of other scientific disciplines in the eyes of the French public were also voiced. With 1993 just around the bend, CNRS is eager to develop an environmental program that functions on a competitive level with those of other countries. At the conference, frequent reference was made to the importance of creating channels of communication between the research community and educators (even at the secondary school level) to develop social awareness of environmental issues. The need for a stronger environmental lobby to exert influence on politicians was brought up as well.

Participants spent the next day and a half attending workshops in

- Ecotoxiology
- Permanent experimental facilities
- Global changes and social sciences
- Biological diversity
- Health and environment
- Soils and biogeochemical cycles
- Littoral areas
- Relations between ecosystems and usage in continental environments
- Methods, models, and theories
- Tropical forests
- Atmospheric pollution
- Continental waters
- Environment and development in Arctic and Subarctic environments
- Environment: questions and perspectives for research.

While the turnout of social and natural scientists, legal professionals, and ministerial representatives at the St. Malo conference indicated much enthusiasm for the interdisciplinary environmental program, the stated goals of the organizers were not achieved. There was neither a recap of projects engaged in during the past year of operations nor a program set for the year to come.

With 75 to 200 people attending each workshop, it was difficult to come to any kind of consensus on a future course of action. Comments from the floor tended toward the introduction of questions and problems in scientific cooperation other than those posed by moderators as the focus of discussion. Debate at an evening round table, *The Environment and North-South Relations; the Scientist's Perspective*, centered on frustrations regarding the management of specific projects abroad. The lack of coherence in workshop discussions with the themes outlined in the director's opening remarks was striking. Consequently, a communication gap exists between administrators and researchers.

NSF/Europe Comment

Through PIREN and Programme Environnement, CNRS has been working toward defining an environmental program and elaborating on its scientific policy for the past 12 years. Administrators are making a big effort to open up their organization through decentralizing, which could encourage cooperative efforts at home and abroad. However, they are struggling with basic questions regarding the scope of their environmental research activities and how they plan to go about integrating the social and natural sciences in environmental research.

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   Lettre du Programme Environnement
   Number 3, September 1991

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REPORTS ON EUROPEAN SCIENCE AND TECHNOLOGY FROM OTHER COMMANDS

Reports

Information on each of the reports listed below was furnished by the following activity. Address requests to: **EOARD** - European Office of Aerospace Research and Development, PSC 802 Box 14, FPO AE 09499-0200

Institute of the Science and Technology of Polymers, Madrid, Spain, by LTC Chet Dymek, EOARD. (5 pp) [EOARD-LR-91-029]

The Institute of the Science and Technology of Polymers (ISTP) in Madrid is part of the Consejo Superior de Investigaciones Cientificas (CSIC) system. Of the five groups who discussed their work with me, two were clearly in a position to make credible claims to leadership in their areas. Dr. Jose Millian's expertise is in relating conformational defects in polymers to local motions, for example, those involved in relaxation processes of polymers. Dr. Fatou competes with the rest of the world's top polymer physical chemists in developing the body of knowledge on the relations between morphology and properties in semicrystalline polymers. There is also some interesting work going on in the photoinitiation of polymerization and some other photo effects on polymers. The ISTP has been well funded in the past few years by the Spanish government, so they have the facilities to be fully competitive.

ABB: Sodium, Sulfur, Heat, and Electricity, by LTC Chet Dymek, EOARD. (5 pp) [EOARD-LR-91-030]

Asea Brown Boveri AG (ABB) is a multinational group formed by the merger of the Swedish company, Asea, and the Swiss company, Brown Boveri. One of the German companies in this group is Hochenergiebatterie (HEB) GmbH in Heidelberg. ABB-HEB employs 40 people in a research and development department. The goal is to feed the technology base that its other departments use to advance the sodium sulfur battery. More than 10 years of experience of ABB-HEB in making beta alumina tubes has led to knowledge that is not published or patented. Combined with their expertise in battery design, this has led to development of 104-Wh/kg batteries that run VWs and BMWs on the autobahn. They are currently in programs that will result in 160-Wh/kg batteries. Moreover they are interested in and capable of pursuing the Air Force goal for a 220-Wh/kg space battery. The ABB also has some interesting ideas to exploit the sodium heat engine for electrical power.

The Heyrovsky Institute-Prague, by LTC Chet Dymek, EOARD. (7 pp) [EOARD-LR-91-031]

The Heyrovsky Institute in Prague is one of ten institutes of the Czechoslovak National Academy of Sciences conducting research in chemistry. The Heyrovsky Institute and the Institute of Macromolecular Chemistry (also in Prague) are the *top two*. Three major technical areas are emphasized—(1) theoretical and quantum chemistry, (2) electrochemistry, and (3) chemical reactivity (focusing on catalysis). Prof. Stepan Urban and his associates have an excellent world-wide reputation for their *ab initio* calculations on the ammonia molecule. They are also making important contributions in studies on other small polyatomic systems. Dr. Zdenek Samec is a dynamic young worker exploring the mechanisms involved in the operation of polymer-based sensors. The particular expertise of the group of Prof. Herman is in crossed-beam experiments involving low-energy positive ions. This group has already collaborated with the Geophysics Directorate of the Phillips Laboratories, and indications are that this mutually beneficial interaction will continue.

Review of the German Hypersonic Research and Technology Program, by Dr. Wladimiro Calarese, EOARD. (7 pp) [EOARD-LR-91-032]

The German Hypersonic Research and Technology Program review took place in Bonn, the Federal Republic of Germany (FRG), on 16-17 April 1991. Pertinent subjects were presented by the scientists involved in the hypersonic technology research program. Dr Hertrich, Minister of Research and Technology, introduced the technical presentations. He stressed the advantages of space exploration, such as air surveillance, checks on disarmament, satellite deployment, and space station support. Since it is important to limit space pollution, reusable systems are needed, such as the Hermes (France), the NASP (U.S.), and the Sanger (FRG). The German Ministry of Research and Technology (BMFT) has partners in the development of reusable space systems, namely Italy, Norway, and Sweden. It also wants the cooperation of the European Space Agency (ESA).

University of Warsaw - Polymer Expertise, by LTC Chet Dymek, EOARD. (5 pp) [EOARD-LR-91-034]

The Institute of Chemistry at Warsaw University of Technology has about 500 students and nearly 120 instructors and researchers. Professor Kuran, leads a group working on the mechanism of catalysis of the polymerization of polyalkylene carbonates. Dr. Rokicki, an associate of Professor Kuran, works on polycondensation reactions to get epoxy resins with increased elasticity and impact resistance. Some very interesting work relevant to polymer electrolyte batteries is being done by a group led by Dr. Florjanczyk. He has expertise in the synthesis of aliphatic polysulfones and PEO blends containing them with 10-3 S cm-1 conductivity at room temperature. Professor Kijenski's group is doing heterogeneous catalysis of reduction reactions, such as the reduction of nitroaromatics to anilines.

Chemistry Research in Wroclaw, by LTC Chet Dymek, EOARD. (5 pp) [EOARD-LR-91-035]

The Institute of Chemistry at the University of Wroclaw is, according Professor Florian Pruchnik (director), one of the best equipped in Poland. There are only 11 Ph.D. candidates among the 140 researchers, but there is some excellent research going on. Professor Pruchnik's interests are centered on the use of rhodium, platinum, and other metal complexes as catalysts for hydrogenation of olefins. Professor Ratajczak's scientific interest of proton transfer has relevance to catalysis, biological processes, and ferroelectrics. He uses IR and Raman in matrix isolation techniques, low-temperature NMR, and *ab initio* calculations to study proton transfer systems. Professor Kisza is an electrochemist with interests in molten salt systems, both organic and inorganic. He has concentrated on the problem of how to measure the exchange current (or standard rate constant) for very fast electrode reactions. There is also some interesting work going on in neighboring institutes in theoretical calculations of matter-antimatter interactions and in polymer blends.

Overview of Aerospace Technological Activities and Programs in France, by Dr. Wladimiro Calarese, EOARD. (5 pp) [EOARD-LR-91-036]

The aerospace technology development in France is proceeding at a good pace. An Air Force team, formed by Lt Col Fred Gilliam and Dr W. Calarese (EOARD), Dr A. Boudreau (AEDC), and Lt Col L. Aldridge (U.S. Embassy, Paris), visited three French facilities and witnessed good progress in both the experimental and numerical fields. Various branches of the Office National d'Etudes et de Recherches Aerospatiales (ONERA) were visited, together with the Institute of St. Louis (ISL) and the aerospatiale branch of Aquitaine. The team was impressed by the level of sophistication of the ongoing research, by the quality of the experimental facilities, the people who are responsible for their use, and by the quality of the scientists devoted to the improvement of numerical techniques and codes. This review is mainly dedicated to problems in aerodynamics.

Proceedings of the 4th OGAMM, by LTC Chet Dymek, EOARD. (126 pp) [EOARD-LR-91-037]

The Fourth OGAMM Meeting was held at the Craiglands Hotel in Ilkley in Yorkshire, England, from 19 to 22 August 1991. The OGAMM program is a highly collaborative multidisciplinary effort designed to provide the technology base needed for the development of the highly sophisticated devices needed for advanced SDI systems. Because these devices are generally intended for imaging, detecting, photonics, tracking, and communications systems, the research focuses on material concepts combining various nonlinear optical, electrical, magnetic, thermal an mechanical functions. In the past year, excellent progress has been made in understanding the influence of molecular structure and surface processes on these properties in a wide range of materials, including impregnated gel silica, multifunctional polymers, polymer blends, and polymer-glass composites. New device concepts and new insights into the role of local order on material processing and properties have also emerged. Greater control of material quality and the ability to predictably combine different functional groups to make truly multifunctional materials were identified as key program objectives at last year's OGAMM meeting. This year it is clear they have been achieved.

Culham Laboratory, by Dr. Kirk Hackett, EOARD. (5 pp) [EOARD-LR-91-039]

Culham Laboratory is one of the leading plasma physics research centers in the world. Dave Ashby's group is developing a MILO high power microwave device and a method of moments electromagnetic modeling code. Jim Eastwood is studying methods of improving electromagnetic particle simulations. Tony Riviere is adding gyrotrons to the COMPASS tokomak for electron cyclotron heating. Alan Newton is refurbishing a reversed field pinch magnetic fusion experiment.

THE EMBASSIES: TECHNOLOGY ROUNDUP

Federal Republic of Germany

For further information on FRG items, contact Mr. Jim McCracken, Science Counselor, American Embassy, Bonn, APO New York 09080-7400.

Science and Technology News in Germany

In September 1991 in Bonn, Research Minister Reisenhuber met with his counterparts from Bulgaria, Poland, Romania, Czechoslovakia, and Hungary, and science and education policy officials from Latvia and the former U.S.S.R. The visitors are interested in the peer review process used in evaluating the former GDR science institutions and in the measures taken to restructure science and research in the new East German states. Also they are interested in participating in West European research programs. Minister Riesenhuber explained that several German programs have been initiated to assist the integration.

- Federal Research Ministry (BMFT) plans a special scientists exchange program to start in 1992.
- BMFT supports fellowship programs (administered by international institutions) for Central and Eastern European countries to the German research data network which in turn would provide access to world-wide data banks.
- Association of Technology Centers in Berlin will prepare conceptual plans for similar centers in Eastern Europe in cooperation with specialists of the respective countries. Fifteen such institutions in the new German states have proven their ability to support new enterprises.
- Social scientists from Central and Eastern Europe are offered the opportunity to cooperate with the Commission for Research on the social and political changes in the new German states.

According to the 1990 annual report of the National Research Center (Center), Juelich, it has 4,700 employees, including 980 scientists. The Center is financed by the federal government and the State of Northrhine-Westphalia, 90 and 10 percent, respectively. The 1990 budget was DM 580 million (about $376 million), and its 1990 research program centered on seven priority areas:

1. Materials research
2. Information technologies (basic research)
3. Health, environment, biotechnology
4. Energy research and technology
5. Nuclear fusion
6. Nuclear basic research
7. Interdisciplinary analysis and methods.

Annual Report of Fraunhofer Society

Recently, the Fraunhofer Society for the Advancement of Applied Research (FhG) published its 1990 annual report. In presenting this report, FhG president Max Syrbe warned that the high level of research funding in the new states and cost-cutting measures undertaken by the Research Ministry had curbed the growth of the FhG. The FhG's 1990 budget was DM 759 million (about $493 million). Public funds provided most of the money though almost 30 percent was provided by market-oriented research and development (R&D) commissioned by the private sector. In response to the tighter budgetary environment, FhG plans to seek commissioned research in additional sectors of the R&D market. In addition, it will adapt its capacities as well as reallocate and stretch out its spending. The FhG has also participated in rebuilding research institutes in the new states. Since October 3, 1990, 9 additional institutes and 10 branch establishments have been planned or set up in the new states.

Main German Science Organizations Liaison Office in Brussels

The German Research Association opened a liaison office to the European Communities (EC) in Brussels. The Coordination Agency to the EC for German Science (KOWI) will inform German scientists about EC programs and promote contacts with researchers in other European countries to develop competitive proposals for EC research funding. Dr. Martin Grabert, head of the new liaison office, said that only 5 percent of the funding German research receives from non-German public sources is of EC origin. The office will also assist German scientists who wish to participate in EC committees and working groups. The DM 1.6 million (about $1.04 million) budget of the liaison office and its counterpart in Bonn will be provided by the German Research Society.

Research Reactor BER II Inaugurated

The neutron source reactor at the Hahn-Meitner Institute (HMI) in Berlin has been inaugurated and is now available for solid-state physics research. Construction took 6 years and cost about DM 200 million (about $7.9 million). BER II will mainly be used in the field of materials structure research.

The HMI is a national research center with about 830 employees. In 1991, its budget was DM 104 million (about $67.5 million). The HMI's task is basic research and application-oriented natural sciences research, especially on condensed matter. In the future, HMI's scientific work will focus on structure research and photo-chemical energy transformation. A research group of the former GDR Academy of Sciences Institute for Electron Physics that works on silicon-based photovoltaics will be integrated into the HMI.

New BMFT Research

The BMFT is funding a new research priority on photonics. Scientists from industry, research institutes, and universities are cooperating in two extensive research projects with a total budget of DM 140 million (about $91 million), of which Dm 80 million (about $52 million) is contributed by the BMFT. The subjects of research are optical connection technology and optical signal processing. Thirty individual projects have been approved for a duration of 4 years. Fifteen groups of scientists have been formed coming from universities, the Fraunhofer Institute for Applied Solid-State Physics, the Heinrich-Herz Institute, Daimler-Benz, Standard Electronik Lorenz (SEL), and Siemens. This initiative has been coordinated with similar activities of the VW Foundation, the German Research Society (DFG), and the State Government of Baden-Wuerttemberg. The program aims at developing free optical signal processing without any intermittent opto-electronic transformation of the information. As the optical signal processing allows a higher transmission speed than does electronic technology, this would constitute the decisive step in the direction of designing an optical computer that would be considerably faster than today's electronic super computers.

The BMFT will support two research projects conducted jointly by universities, research institutes, and industry:

1. Reference Model for Safe Information Technology Systems (REMO) aims at developing an immune system for computers against data theft and computer viruses. In addition, the project tries to find ways to retrofit personal computers and work stations that are already operating with safety equipment. The BMFT will spend DM 11 million (about $7.1 million) from 1990 until 1993 on this project. The research participants of REMO include the Industrieanlagen-Betriebsgesellschaft in Ottobrunn, the German National Research Center for Computer Science (GMD), and Siemens.
2. Correct Software (Korso) is meant to develop monitoring systems to check the ability of a program to work correctly under any circumstances. The availability of such a test system might, for example, be helpful in proving the reliability of an air space control program or of other security-related computer programs. Main participants in this program are Siemens, the German National Research Center for Computer Research (GMD), the University of Karlsruhe, and the Technical University of Munich. From 1991 until 1994, the BMFT is funding the program with DM 14 million (about $9.1 million).

Within the framework of its research funding program, Biotechnology 2000, the Research Ministry has announced a new funding program for research on immune sensors for gaseous substances. The project's goal is to accelerate the development of bio-sensors for monitoring air contamination in the environment and in the work place and to make them marketable. The sensors are expected to identify substances in very low concentrations (on the PPB level). The sensitivity of the bio-sensors will be reinforced by another biological reaction, enzymatic detection. The sensors work on the basis of antigene-antibody reactions: the noxious substances to be measured (antigenes) are identified via the according antibody. The BMFT will spend DM 2.4 million (about $1.5 million) on the project which is being carried out by the Draegerwerk in Luebeck, the University of Luebeck, and the Institute for Experimental Biology and Medicine in Borstel.

Scotland

For further information on Scotland items, contact Mr. Jeffrey Lutz, Science Counselor, American Embassy, London, PSC 801 Box 38, FPO AE 09498-4038.

Scotland Has a Silicon Valley

Silicon Glen, Scotland's answer to the California valley named for the same element, is a misnomer. It isn't a geographical entity at all, simply a nickname for electronics firms that inhabit the Scottish lowlands. It also predates its American counterpart. Ferranti, the defense electronics company later acquired by the GEC conglomerate, relocated to Edinburgh in 1941 to avoid Nazi bombs. In 1946, NCR began manufacturing cash registers in Dundee, and IBM opened its Greenock manufacturing plant 5 years later. The ensuing decades have witnessed substantial growth, the Scottish electronics industry now employs over 45,000 people, nearly 13 percent of the industrial workforce.

The bulk of foreign investment in Silicon Glen (the Glen) comes from the U.S. In 1989. American-owned firms employed 41.6 percent of Scotland's electronics industry workforce. European Community-origin investment accounted for only 4.1 percent of employment, while other (including Japanese) investors employed 5.5 percent. As of September 1990, over 60 U.S. And Canadian electronics firms had established production facilities in Scotland. The largest single investor is IBM: its Greenock plant turns out over £1.9 billion ($3.5 billion) worth of personal computers (PC) annually. The value of its exports exceeds that of the entire Scotch whisky industry.

The dominant position of the U.S. in the Glen may be ending. In 1990, the annual amount invested in the Glen by Japanese firms exceeded the flow from the U.S. for the first time. Scottish development officials believe that will prove to be a fluke; the Gulf War and the U.S. recession depressed the expected U.S. investment. But given Japan's long-term interest in cracking the European electronics market and our continuing economic difficulties, it could mark the beginning of a trend.

The Glen's stable, English language culture, common law tradition, and long association with the electronics industry makes it an attractive place for inward investment. Another attraction is the plentiful supply of cheap, nonunion, university-trained professional and technical personnel. The availability of generous government assistance and good transport infrastructure also play a part. Finally, the perceived need on the part of foreign firms to establish a European presence before the creation of the single European market in 1992 also is an important factor in many firms' calculations.

The biggest single factor drawing foreign electronics firms to the Glen may well be the perception that it (not Ireland, Wales, or Southeastern England) is the place to be if you are in the electronics business. The Glen owes a great deal of the credit to IBM, its largest and most successful resident, for assisting in its creation.

The IBM Greenock facility is huge. Annually, it produces over $2.5 billion worth of computers and related products, satisfying between one-fourth and one-third of Europe's total annual demand for PCs. Employing 2,500 people, it does everything from product development to final shipment on site.

Output and employment are only part of the services that IBM provides. The policy of producing in-house major components of its final products, and encouraging local sourcing has fomented the development of the support infrastructure accustomed to supporting high-tech industry. In 1990, IBM Greenock bought £231 million ($400 million) worth of inputs to production from Scottish vendors, almost one-third of its total procurement. Almost 8,000 jobs have been created by the Scottish vendors that have sprung up to supply IBM's needs. Other firms have followed IBM's example. Digital, for example, produces its own 4-megabyte dynamic random access memory devises (DRAM) for consumption in its Ayr computer plant. The Scottish vendor base is considered by IBM as among the best it uses anywhere. This partnership probably can expand to meet the needs of new entrants who want to crack the European electronics market.

Judging from the list of electronics companies that operate in the Glen, many other firms agree. In the early 1980s, NCR switched from producing cash registers to automated teller machines (ATM). It now produces 40 percent of the world's supply of ATMs in Dundee. In 1982, NEC Semiconductors Ltd. began producing chips; it started as an assembly and test plant, very much in screwdriver plant mode. Now, it is a major wafer fabrication plant. The plant does everything necessary to transform a polished blank silicon disk into advanced integrated circuits such as 4 megabyte DRAMS. The firm already has invested £158 million on site, and a £200-million expansion is underway. When completed in mid-1993, the expanded facility will produce 16-64 megabyte memory devices for export into Europe, the U.S., and Asia.

Why the Glen? The necessary infrastructure already was in place, other high-tech firms already were there, and subcontractors with needed skills such as clean room construction/maintenance, were available.

Motorola is becoming one of the biggest foreign investors in the Glen. It produces semiconductors in East Kilbride, and assembles cellular telephone products in a temporary facility in Livingstone. The finishing touches are being applied to a mammoth facility at Easter Inch. When it opens, Motorola will shift cellular telephone production to the 400,000-square foot factory which will employ 2,000 people. At that point, Motorola will replace IBM as the Glen's largest nondefense electronics company in terms of employment. The site allows expansion to 800,000 square feet, which would make Easter Inch almost as big as Motorola's Libertyville, Illinois, plant.

Motorola sees the Glen as the logical place to centralize production of cellular telephones for the European market, which in 1990 actually was bigger than the similar market in the U.S. Motorola will manufacture a variety of national standards at the Easter Inch plant, taking advantage of the high degree of commonality inherent in cellular telephones to create cost-reducing economies of scale.

More companies are coming. Japan's JVC recently established a plant making televisions and computer monitors in East Kilbride, and OKI has set up a printer plant in Cumbernauld. Others are both expanding and deepening their Scottish operations. Hewlett Packard (H.P.) is expanding its production of test equipment for digital cellular telecommunications, mostly for export to Europe. H.P. sees the Glen as the optimal place to do it because there it can produce test equipment for Europe's GSM (digital cellular) standard cheaper than in the U.S. H.P. can ship it to continental markets faster and cheaper than it could using a stateside base.

Serpents in the Garden

Even though the Glen is attractive, can point to a track record of success for its residents, has a good vendor base, and offers incentives to investors, it does not seethe with the creativity, and does not exude the dynamism of its American cousin. In fact, it pales in comparison in terms of innovation, and frankly, importance. Why?

Some critics argue that the Glen has failed to reach critical mass because the psychological barrier of seeming to be so far from Europe's heartland has kept firms from investing. That probably is true to a point. Getting goods to market can be difficult when, as IBM puts it, "Scotland's biggest traffic jam is the M-25 around London." Others blame the traditional migration of Scotland's best brains and entrepreneurs to England and the U.S. Both explanations are true, but they do not provide the whole answer.

Blame also must be laid on the staid, tried-and-true way business traditionally has been done there. Stick to what you know. Deepen product lines, rather than broaden them. Don't diversify except through acquisitions. GEC Ferranti personifies that approach.

GEC Ferranti is big; it employs over 5,100 people in the Glen in its four divisions—radar, navigational, display, and logistical systems. That workforce is high tech; 1,600 are professional scientists or engineers. However, all its efforts are concentrated in the low volume, high unit-value defense electronics sector. Precious few of the systems it produces and markets are targeted on the civil sector.

That purity of focus may have made the firm a reliable supplier of highly complex military equipment, but it prevented it from becoming an engine for regional development. As a producer of small quantities of high value-added goods, its input needs were relatively small. Therefore, its coat-tails (measured in the number of vendors that sprung up to supply its needs) were short. Had GEC Ferranti's product mix included some high-volume, input-intensive products, the Glen's early development could have been much more rapid.

GEC Ferranti's monomania continues to affect adversely the development of the Glen. With the end of the Cold War, the defense electronics market has contracted, and it shows every sign of contracting still further. GEC Ferranti recently announced that it would lay off 657 people at its Scottish facilities, and additional layoffs are anticipated.

Yet, the firm still rejects diversification. Company spokesmen told us that they pin their hopes for future business on Eurofighter and the opening of the Eastern European defense electronics market. They have no plans to use the firm's high-tech expertise to beat swords into plowshares.

Another key to the Glen's underperformance relative to its American cousin lies in the kind of inward investment that the sweet financial incentives Scotland offers has attracted. In 1988, SUN Microsystems came to the Glen lured by the offer of an essentially free development site and a generous package of grants. The combination removed virtually all the risk SUN faced in setting up its first foreign operation. Now SUN certainly cannot be accused of GEC Ferranti-like stodginess. As a leading edge manufacturer of PCs and workstations, it is highly responsive to market forces. SUN, like many other electronics industry transplants to the Glen, is a screwdriver plant. As the European outpost of a home office, which maintains responsibility for research and development and the introduction of new products, SUN's presence in the Glen does nothing to develop an indigenous climate of innovation. Since SUN assembles only products using virtually 100 percent imported inputs, like GEC Ferranti, it has no coat-tails. SUN's experience is so typical of the Glen that, according to one recent study, only 15 percent of the Scottish electronics industry's inputs were supplied from Scotland.

The Glen also suffers from a failure of entrepreneurship. SUN, like its sister screwdriver plants, simply does not spin off clones like the big California companies did (and do). The "I can do it better" spirit, which motivated so many Silicon Valley garage startups, has not flourished in the barren soil of the assembly industry.

Those few who did spin off found Britain's capital market much more hostile to supplying venture capital than its American counterpart. The British financial market will not fund high-risk, high fixed cost, long repayment period projects, especially if those projects are advanced by engineers rather than businessmen.

Finally, screwdriver plants come, and screwdriver plants go; their roots are shallow, and they are relatively cheap to write off in hard times. Wang, for example, shut down its Stirling operation in mid-1989 with a loss of 240 jobs.

Conclusion

Silicon Glen is not Silicon Valley. It does not have to be. As an English-speaking development zone on the periphery of Europe specializing in high-tech industries, it already has enjoyed success. If its oldest inhabitants change to meet new political and economic realities, and its newest transplants evolve from screwdriver plants into full integrated operations (as did such current stalwarts as NCR, NEC, Motorola, and Digital), the Glen should have a vibrant and exciting future.

Spain

For further information on Spain items, contact Mr. Robert G. Morris, Science Counselor, American Embassy, Madrid, APO NY 09285-8500.

Materials Science Institute of Seville

The Materials Science Institute of Seville (Instituto de Ciencia de Materiales de Sevilla [ICMSE]) is one of four associated centers for research in the field established by the National Research Council (Consejo Superior de Investigaciones Cientificas [CSIC]) in Seville, Madrid, Zaragoza, and Barcelona. The investment and the work of ICMSE and CSIC represent a major effort by Spain to excel in a field in which it has less experience than biology, chemistry, or physics and in which there may be more immediate economic payoff.

Located in four different buildings of the part of the campus of the University of Seville (University) devoted largely to science and engineering, the ICMSE was more an interdisciplinary program. In late 1991, it moved into its own quarters and became a self-contained research unit. As a mixed institute, it is supported jointly by the University and CSIC. Madrid's is strictly a CSIC institute, Zaragosa's is like Seville's, while Barcelona's receives support from the autonomous university, CSIC, and the Autonomous Region of Catalunya. The joint institutional effort involving the four buildings draws on the faculties of physics (solid-state physics), chemistry, computer science, and pharmacy (inorganic chemistry).

The work will be united in one building on the site of the Seville Universal Exposition (Expo) after the 1992 event ends. Indeed, seven CSIC institutes and a good part of the science and technology (S&T) faculties of the University will also relocate there in buildings constructed for Expo and will form the nucleus of a technological or research park. Local authorities hope that exhibitors at the exposition like Sony and Siemens may also retain their buildings for use as corporate research laboratories.

With 70,000 students, the University claims to be Spain's largest after Madrid's Complutense. Although theoretically all Spanish universities have open admissions nationally, they tend to be regional. Andalucia, Spain's large and relatively undeveloped southern autonomous region, supports other universities besides Seville and effectively limits study at each to students from nearby districts. Seville's main building since 1958 has been the "Tobacco Factory," long the center of the state monopoly and famous from the opening scene of the opera as the spot where Carmen first bewitches the ill-fated Don José.

Organization and Budget—Growth Areas. The institute dates only from 1986. It has a staff of 79: 11 CSIC researches, 25 university researchers, 5 technicians, 12 contract researchers, and 26 student research assistants. They work in eight groups in four main areas: (1) defects, mechanical properties, and reactivity of solids; (2) structural studies of crystalline and amorphous solids; (3) physical chemistry of surfaces and interfaces; (4) synthesis and preparation of new materials and molecular solids.

The annual budget of around $1.7 million comes largely from the government. The CSIC pays $700,000 directly to the University for fixed annual expenses. Industry puts up about 10 percent of the rest; the autonomous region also contributes.

European Community Money Supports Individual Projects. Director José Luis Perez Rodriguez is a physicist specializing in x-ray crystallography. He says there is no difficulty filling CSIC posts and he hopes to expand the number of investigators to the same number as from the University. Perez adds that the budget depends on output as measured by published journal articles and papers presented at meetings. In 1990, CSIC personnel published 75 journal articles and papers presented at meetings. In 1990, CSIC personnel published 75 journal articles and presented 55 papers at meetings. Thus, government support of research and development (R&D) will decrease in 1992 for the first time in many years. After an average annual increase of 23 percent from 1983-1990, CSIC has not been hit too badly. European Community (EC) infrastructure funds contribute to the annual budget, and $10 million in such funds have been shared by materials, microelectronics, and biology institutes in Seville to buy equipment and fittings. As is typical in Spain, CSIC pays fixed expenses. Other parts of the government (including the national R&D plan), together with EC and local public and private funds, go to support individual research projects.

Coordination With Other Institutes Valued. Coordination and cooperation between the four national materials centers is institutionalized in at least two ways: (1) the international advisory committee and (2) annual joint scientific meetings. Manuel Cardona chairs the advisory committee. He is a Spanish physicist well known in the U.S. and is now at the Max Planck Institute for Solid-State Physics in Stuttgart. Among the nine other members are Nobelist Karl Alex Mueller of IBM-Zurich and two Americans--E. Mendez of IBM-Yorktown Heights and T.E. Madey-Rutgers. The advisory committee meets for 3 or 4 days annually and works with all four materials centers.

This concept of an advisory or visiting committee is relatively new and still uncommon in Spain. Perez knew of one for biology centers, but believed the committee had never met. Microelectronic centers use international advisers. While proud of the relation of his center to the advisory committee, Perez said that it could be more useful and contribute a bit more to the center. The committee would be more effective, he thought, if it came more often or stayed longer.

A recent conference in the annual series not only united Spanish materials scientists, but also had six invited speakers from abroad. Three hundred scientists delivered 165 papers over a 3-day period. The ICMSE also organizes seminars. Postgraduate researchers assembled in Seville for a week in 1991 on analysis of materials by x ray, electron, and ion beams. Agustin Rodriguez Gonzalez-Elipé (surface physicist) and Odriozola (surface chemist) are not only spark plugs in the ICMSE but take an active role in organizing the conferences and courses.

Besides contact with the U.S. through the advisory committee, ICMSE has had joint projects with A. Heuer, Case-Western Reserve (properties of zirconium oxide) and J. Routbort, Argonne (ceramics). Case Western Reserve, UC San Diego, University of Texas, and Rutgers, and ICMSE scientists have worked closely with groups at Northwestern, UC Berkeley, and University of Florida in Gainesville. Some of the contacts were made originally under the U.S.-Spain S&T agreement that expired in 1989.

Solid-State Physics. Since a visitor views the work by visiting the buildings where it is carried out, the correlation between the buildings and the main groups listed above may be inaccurate. A first glimpse is of a well-equipped laboratory with many devices for x-ray diffraction, fluorescence and spectrometry and for electron micrography, baked up with a MICROVAX 3100 computer. Bigger VAX machines are available online from the neighboring computer center. In the solid-state physics laboratories, a nine-member group studies structure and mechanical properties of ceramics. Most are zirconium oxide (ZR02) composites or aluminum oxides with silicon. Researchers coordinate mechanical behavior as a function of temperature (77-1500°K) with microstructure. Other work looks at effects of defects in transition, metal oxides, migration, and deformation.

Molecular crystals and metallic glasses, including ferromagnetics, are subjected to differential calorimetric measurement through phase transitions as well as x ray and photographic analysis. Study of such materials' electrical properties will be next. A second electron microscopy facility has four machines, and there are adequate support rooms for sample preparation (organic as well as inorganic), a computation room, and a dark room. Solid kinetic studies relate directly to solid solar cells, catalysts, and low-temperature sintering of ceramics. Table 1 provides a sample list of solid-state physics publications.

Table 1. Solid-State Physics Publications

- High-Temperature Creep of Yttria-Stabilized Zirconia Single Crystals
  Journal of the American Ceramic Society
  73 (1990) 2452
- A Lattice-Dynamical Evaluation of Thermal Parameters in Chlorohydrocarbons
  Acta Crystallogaphica A46 (1990) C-366
- Nonisothermal Crystallization of a Nickel-Based Glass
  Basic Features of the Glassy State,
  Editorial World Scientific (1990) 355.

Physical Chemistry. X-ray, photon, and electron spectroscopy back up work on surfaces and catalysis in the faculty of chemistry. Again, the focus is on ceramics and oxides, although there is also a laboratory for organometallic compounds. Other research subjects have included catalysts of rhodium with lanthanum oxides and catalytic reductions of nitrogen oxides using gas chromatography and mess spectrometry, adsorption, and infrared spectrometry. Table 2 provides a sample list of physical chemistry publications.

Table 2. Physical Chemistry Publications

- Imaging of Biomolecules With the Scanning Tunneling Microscope
  Journal of Vacuum Science & Technology A*
  (1990) 635
- Carbon Monoxide Adsorption on Rhodium (1) and on Metallic Rhodium Supported on Titanium Oxide
  Journal of Molecular Catalysis, 62 (1990) 171.

New Materials. Here the emphasis is on new materials related to common, naturally occurring silicates. The goal is the fabrication of new mat ls: ceramics, catalyst supports, large-area abso . Work on organic compounds intercalated in laminar si..ates may lead to new ceramics of interest. A project on organometallic compounds uses vapor-phase deposition, ultrasonic generation of aerosols, and thin-film fabrication of materials containing phosphorous, arsenic, and others. Table 3 provides a sample list of new materials publications.

Table 3. New Materials Publications

- MU3-2-Methylallyl Phosphine Complexes of Nickel (11)
  Polyhedron 9 (1990) 757
- Rotational Isomerism is BIS (Carbon Dioxide) Complexes of Molybdenum Generated by Conrotatory Motion of the CO2 Ligands
  Organometallics 9 (1990) 1337.

National Microelectronics Center-Seville

The National Research Council (CSIC) operates the National Microelectronics Center (Centro Nacional de Microelectronica [CNM]) in three cities. The Clean Room, Silicon, and Chip Design Departments are in Barcelona; Madrid is home of the Compound Semiconductor Department. The Department of Analog Circuit Design in Seville started as a microcircuits design group at the University of Seville and then became a joint CSIC-University Center before incorporation into CNM in 1989.

Work in microelectronics is driven by the same force as new materials to catch up in nontraditional areas of research and thus jump on the train of home-grown technological innovatio'. and self sufficiency. It will, of course, take more time to see how such recent efforts as CNM affect the economy. The electronic industry is still small in Spain and does little research. In what there is, foreign subsidiaries are strongly represented. For 1992, industry as a whole in Spain is estimated to stay at 0.32 percent of GDP (the same as 1991 and only up a hundredth of a percent over 1990). Government support will fall 4 percent in 1992. While in 1990 Spain sold only 19 percent as much technology as it bought, the rate was up to 27 percent for the first 6 months of 1991.

Organizatio.. and Budget: The Industry Connection. A visit to CNM is easily combined with one to the materials center since they are both in the S&T complex of the University. The CNM is actually in the computer center, or the Information Sciences Center of Andalucia (Centro Informatico Cientifico de Andalucia [CICA]), as it is formally known. This center, another creation dating from 1989, is operated by CSIC, the University, and the Autonomous Region of Andalucia. Its gleaming marble spaces are jammed with Convex, VAX, MICROVAX, and Hewlett-Packard computers to the point that it is already under expansion to better house the CNM Analog Design Department.

The director, José Luis Huertas Diaz, described the department on a recent visit and tour of the facility. Huertas received his Ph.D. in Holland in 1973 and has been a professor at the University since 1981. Operated by CSIC but with close ties to the University, the department now has a staff of about 35, with 10 Ph.D.s and 15 research assistants. The rest are technicians and administrative personnel. The annual budget appears to be about $2.5 million: CSIC (mainly infrastructure)-$200,000, the autonomous region-$500,000, industry-$1,400,000, the EC- $400,000. Other unreferenced money comes from the government for specific projects.[1]

Outreach--A Necessity. In such a frontier field as microelectronics, it is not surprising that there is considerable contact with laboratories abroad. These include UCLA, UC Berkeley, and Texas A&M, and others in several EC countries plus Switzerland. Contract work with industry, which can include certain EC programs (and make all the bookkeeping fuzzy), has involved firms in France and Italy, Hughes (U.S.), Fujitsu-Spain, firms in Austria as well as, of course, Spain. Like the materials center the microelectronics center also has contact with the world through an advisory committee of five scientists from the U.S. and Europe.

Huertas said the CICA at one point had more contract work with firms outside Spain than national industry. Nevertheless, there is a big effort to serve Spanish industry, including small and medium enterprises (SME) that are too small to do their own research. For the SMEs, the CICA tried to help them apply microelectronics to their business, not necessarily design new chips for them. Two success stories have been pressure and optical sensors for the Spanish auto maker Seat and electronic electric utility meters for another Spanish manufacturer. Table 4 provides main areas of CNM research.

[1]We say "appears" because Spanish R&D budgets have a way of being more anecdotal than attestable. The industrial support, which includes some from telefonica, Alcatel-Spain, and Fagor, in this case is very high for a Spanish government laboratory, and nearly twice the already high proportion for CNM as a whole.

Table 4. CNM Design Work

- Analog and analog-digital VLSI (very large-scale integration) Design
- Generation of software tools for CAD (computer-aided design)
- Digital system design.

Most designs apply to silicon. The CICA collaborates closely on many issues related to silicon with the departments in Barcelona dedicated to that material. Little integrated circuit (IC) or chip fabrication is carried out in Seville, although there is some custom work for Barcelona and all ICS and chips contracted out are experimentally evaluated in the Seville center. A cluster of SUN and Hewlett-Packard workstations is dedicated to DAD VLSI design. Access to other computers in CICA support the other work.

Research interests of the principal staff are the following subtopics of the general areas.

- Multivalued logic (including fuzzy logic)
- Sequential machines
- CAD and nonlinear networks
- Analog neural networks
- Analog nonlinear microelectronics
- CAD of analog circuits
- Monolithic filter and oscillator design
- Digital systems timing
- Systems testing
- Computer architectures.

Table 5 provides a list of analog and digital circuit design activities.

Table 5. CNM Analog and Digital Circuit Design Activities

- Design of analog ICS
- Design of monolithic neural networks for nonlinear programming
- Logic designs
- Timing problems in integrated systems
- Design of multivalue logic circuits, including fuzzy logic
- Fault-tolerant system and software design
- Adaptation and tuning of a CAD environment
- Development of new CAD models for all the design areas given above
- Development of design tools
  - Automatic design of operational amplifiers, sequential machines, self testing.

It's All In The Computer. A tour of the facility is not very exciting. One sees mostly a lot of activity around whirring computers in bright, well-ventilated rooms, but none of the intriguing collections of pipes, wires, pumps, and ovens more typical of a physics or chemistry laboratory. If one did not look closely, he could just as well think he was in an insurance company. In the 5-year period ending in March 1991, personnel published 41 research papers in international journals such as *Electronics Letters* (U.K.), *Proceedings of the IEEE* (U.S.), *IEEE Journal of Solid-State Circuits*, and *IEEE Transaction - Circuit Systems*.

The computer configuration for IC design recently consisted of the following (not including spares):

- HP-9000/370, 8-megabyte RAM, 500-megabyte disk
  Sun 3/260, 8-megabyte RAM, 280-megabyte disk
  VAX cluster
- 8530 CPU, 6400 CPU
- 32-megabyte RAM, 1550-megabyte disk Convex 220, 64-megabyte RAM, 3 gigabyte disk, with VAX 11/785, 16-megabyte RAM, 900 megabyte disk.

Concluding Remarks - No Sure System

It is too soon even for a specialist (Spanish or otherwise) to tell whether the materials and microelectronics centers will be a success and contribute to lowering Spain's technology deficit. They both have and advantage over some other centers--industrial support. Although industry remains small in Spain, uncommon aid through contracts and other means has largely shielded both these Seville centers from effects of R&D cuts by the national government. Contributions from the autonomous region are also helpful. They are relatively large for Spain when the lower economic development of the region is taken into account. The EC connection also gives the researchers contacts that are in short supply in Spain.

If we had to make a nonspecialist's bet, we would give slightly higher odds for success to the Seville microelectronics work than to the work on new materials. The work at CNM seems better supported, conceived, and plugged in to the world. In comparison, the work at the materials science center appears more specialized, more remote, less coordinated with its sister centers.

Both centers have imaginative and enthusiastic scientists who are well trained, well equipped, and hard working. If the centers don't succeed, it won't be for their lack of effort. Spain may still need to ponder that its efforts in S&T remain modest.

United Kingdom

For further information on United Kingdom items, contact Mr. Jeffrey Lutz, Science Counselor, American Embassy, London, PSC 801 Box 38, FPO AE 09498-4038.

U.K. High-Tech Laser Industry Expects Drop in Domestic Market

The U.K. laser industry is being severely affected by cutbacks in research and development (R&D) funds, most notably in the domestic market. The reduction in real terms is the budget for the Science and Engineering Research Council (SERC). Consequently, their reduction in support for universities has been a severe blow to the U.K. high-technology instrument makers, especially the laser industry. This has been coupled by a virtual halt in Ministry of Defence-funded R&D. Additionally, there has been a recession-induced reduction in industrial research, especially in those industries that have been privatized recently. This resulted in a 5-percent decline in the domestic laser market in 1991. This cutback follows the 20 percent reduction in this market in 1990.

The U.K. has historically been a major contributor to science and high technology, dramatically exemplified by its contributions to laser technology. The nation's ability to exploit this technological lead has been handicapped by its inability to foster the required startup industries because of the weakness of the domestic market. The U.K. laser industry has been able to rely on only 30 to 40 percent of its sales from domestic customers. Competing on the world market to survive has been difficult because of the additional overhead. At the same time, it has had to compete with the domestic laser industries in the highly developed nations that constitute the bulk of the high-technology market. Consequently, one more U.K. industry finds itself at a disadvantage in its attempt to create jobs and profits by exploiting the significant advances made by British research and invention. The plight of the laser industry has led to a call by the leaders of the U.K. Laser and Electro-Optical Association for a review of government policy regarding overall funding for and fostering of science and technology (one of Britain's strongest assets). It is not looking so much for direct support for its own research as for support for a general expansion of U.K. R&D which would increase dramatically its domestic markets.

House of Lords Science and Technology Committee Reports on 1991-92 Science Budget

The United Kingdom (U.K.) science budget is the annual allocation of the Department of Education and Science (DES) to the five U.K. research councils. The councils and their current budgets (in millions) are:

1. Agricultural and Food Research Council (ARC) - £93.5
2. Medical Research Council (MRC) - £200.4
3. Natural Environment Research Council (NERC) - £122.6
4. Science and Engineering Research Council (SERC) - £451.3
5. Economic and Social Sciences Research Council (ESRC) - £35.5.

The councils use their appropriations to finance research in their own institutes. In addition, they fund university research and teaching grants and postgraduate awards.

After complaints by council heads and scientists, the House of Lords Science and Technology Committee reviewed the 1991-92 budget and concluded that it fell short of what is required to provide the basis for continuing development of the country's scientific base. The research councils would have to make deep cuts in new projects, research grants, and student aid simply to meet past commitments. All councils planned to cut grants and aid. While the ESRC said it would cut its new research programs on global environment change, the SERC announced closure of the nuclear structure facility at Daresbury Laboratory. The NERC said it would only fund 40 percent of its highest priority project—the terrestrial initiative in global environment. In the committee's judgment, these cuts would threaten the very seed core of the U.K. science base.

The committee reported that inflation was the main cause of the budget crisis. The 2.7-percent rise over the 1990-91 budget did not meet government estimates of 6 percent inflation for the 1991-92 period. The committee also doubted DES claims that the 1991-92 settlement actually was an increase of 6.7 percent which would maintain the value of the budget in real terms. According to the committee, the DES arrived at this figure by adding the budget hike plus £36.5 million extra that DES calculated the councils had available. The DES computed the latter sum by rescheduling postgraduate tuition fees, freeing ABRC funds reserved for possible European Community (EC) project expenses, and showing as available £23.6 million earlier allocated but not spent for two major capital projects.

The committee found that even if DES figures were correct, research council cost hikes, especially wages, have outpaced inflation. Most witnesses agreed that scientific research and development inflation was 1 to 2 percent higher than general inflation. The committee also found compelling testimony by ABRC and council witnesses that the settlement was misleading because the £23.6 million for capital expenses was already committed. The DES treated this as available money.

The committee concluded the lean science budgets in the 1980s also contributed to the 1991 crisis because they left the councils overstretched. Long-term expenses and international subscriptions additionally limit council spending flexibility. At least 40 percent of research council spending cannot be terminated at short notice. The councils also have little or no control over the cost of subscriptions to EC and other international institutes and are especially vulnerable to fluctuations in the value of the pound. The committee faulted SERC budget practices, criticizing it for estimating its 1991-92 budget grant and committing its funds before learning the actual budget figures.

The main committee proposals included a £12 million supplemental allocation to the research councils to be followed by a government review of spending priorities. The committee recommended the government lessen inflationary pressures on the councils by absorbing fluctuations in pound exchange rates above 2 1/2 percent and letting the councils fix researchers' salary levels. It also found that council spending was skewed in favor of big science projects and multinational facilities. Since these could be maintained under current funding levels only by cutting other areas of research, the committee recommended the government look hard at U.K. large and joint facilities and programs.

The government response rejected most of the committee's recommendations and the underlying rationale of its report. At the same time, it admitted that some councils have financial problems, but denied the government was to blame or that a crisis existed.

High points of the government response include

- Do not increase budget beyond £7 million supplement
- Look at large and joint facilities and decide how best to balance the scientific research program
- Reject the need for additional research council authority to fix research pay scales because since they follow civil service pay, uncoupling them would be too unpredictable
- Dismiss the need for government to absorb large swings in the pound exchange rate.

U.K. Revises Strategy for Support of Core Science

The Science and Engineering Research Council (SERC) science board has published a third, revised edition of *Strategy for Support of Core Science*. The board has revised and updated its strategy in the light of changes in its program and funding levels. In his foreword, chairman of the science board, Professor David Wallace, comments that the board's task is immensely challenging and exciting. The subject areas encompass a very wide range of science that underpins much of technology, and its role in the provision of trained manpower is vital for U.K. education, industry, and commerce.

A key element of the board's policy is the balance between the various mechanisms of support--grants, fellowships, studentships, and access to national and international central facilities. Collaborative work is also strongly encouraged with industry, other board of SERC, and other research councils and increasingly through European Community channels. Professor Wallace states that the board and its community is passing through a difficult period. Financial stringency requires that selectivity will continue to be an inescapable feature of research funding. Nevertheless, the board will strive in the national interest to support the highest quality science.

Highlights of the Strategy for Support of Core Science Balance of Support. Research grants remain the largest single component in the science board funding. Board policy is to increase the proportion of its funds directly supporting universities and polytechnics. The board is convinced that the responsive mode grants are the heart of its research grants support (on which the health of the core sciences depend) since they allow the best scientists to carry out research of their own choosing.

Initiatives. These continue to be an important part of the board's strategy because they allow important interdisciplinary areas of science to benefit from enhanced and coordinated support for 6 years. The board's portfolio of 13 initiatives can be grouped under three headings: (1) mathematics and computational and cognitive science (2) molecular/biological sciences, and (3) chemistry, physics, and related technologies. The board is involved with six LINK programs and are seeking opportunities to develop others, particularly from within its initiatives.

Interdisciplinary Research Centers. These multidisciplinary research groups based at a higher education institute are now regarded as an additional research grant mechanism and as such are to be funded from the council's normal budget. These groups often involve academics in nearby institutions and have interactions with industry. The science board announced the establishment of an interdisciplinary research center (IRC) in cellular and molecular studies of simpler nervous systems at Sussex University.

Postgraduate Training. Postgraduate training in the core sciences is important nationally and is a vital element of the board's program. The board is seeking a 5-percent increase in research student numbers annually from 1993-94 in line with the arguments presented to the board by the Industrial Strategy Panel and the Mathematics Strategy Review.

Central Facilities. The board considers it to be essential for the work of its community to provide access to a basic set of radiation sources for the study of matter. To this end, it supports several major facilities, both national and international, for use by the U.K. academic research community. The objective of the board is to seek to provide access to world-class facilities for U.K. research workers. Currently these facilities are: The Spallation Neutron Source (ISIS) and the central laser facility at the Rutherford-Appleton Laboratory, the high-flux reactor at Institute Lave Langevin in Grenoble, and the synchrotron radiation source at the Daresbury Laboratory. The SERC also provides the U.K. subscription to the European Synchrotron Radiation Facility now under construction.

Industrial Links. The board is seeking to improve links with industry. The report of its industrial strategy panel *Science Board and Industry* has recently been published. To maintain an informed contact with industry, the board will continue to seek industrial members throughout committee structure and to encourage the holding of meetings at industrial venues.

Computing. The board's community is a major user of the research councils' Cray XMP-48 and other national supercomputers. It has funded the computational science initiative, the aim of which is to provide local facilities for high-performance computing, to respond to the developments in distributed computing in individual academic departments. The board has also been increasing its support for parallel processing.

Antibodies Are Made Without Immunization

Antibodies are the protein molecules in the blood that help defend us against invaders (antigens) such as bacteria and viruses. Although their use in medicine and biotechnology is on the increase, their isolation requires immunization. This is often both impractical and complicated. For example, it is particularly difficult to immunize against human tissue to make antibodies to image and destroy cancer cells.

A team at Cambridge has used its library of more than 10 million antibody variants displayed on the surface of phage (bacterial viruses) to select those phage that bind to an artificial antigen. The antibodies are then made by growing the selected phage in bacteria. The scientists have made human antibodies that bind tightly to both large (proteins) and small molecules (haptens).

In this new technique, scientists mimic the immune process. They cloned antibody genes from the human gene repertoire into the phage DNA in such a way that when a phage infects a bacterium, it also instructs it to make antibody. This is not a complete antibody but a fragment carrying the antigen binding site which attaches to the phage coat. Each phage displays a different antibody on its surface.

To find an antibody that binds to a particular molecule (artificial antigen) from the repertoire of more than 10 million phages, the phages with displayed antibodies are exposed to a surface to which the antigen is attached. The phages that do not bind can be washed away, and those that have bound can be harvested from the surface. The process can select a single binding phage out of this vast repertoire. The selected phage will carry the genes for making the desired antibodies. These antibodies can be improved by mutation and further rounds of selection, as in the immune system. The free antibodies can then be made in bacterial culture.

Head of the Cambridge team Dr. Greg Winter said, "Once the phage repertoire has been constructed, the same repertoire can be used many times to make antibodies against different antigens. We are now trying to make even better antibodies of therapeutic value, for treating cancer and aids for example. The process is a big step towards eliminating the use of animals when making antibodies."

The collaborative work has clear commercial implications. The MRC has an equity stake in Cambridge antibody technology (CAT) and revenues will be shared. The CAT has rights to license the technology.

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